ELEMENTARY GENERAL SCIENCE

BOOK III

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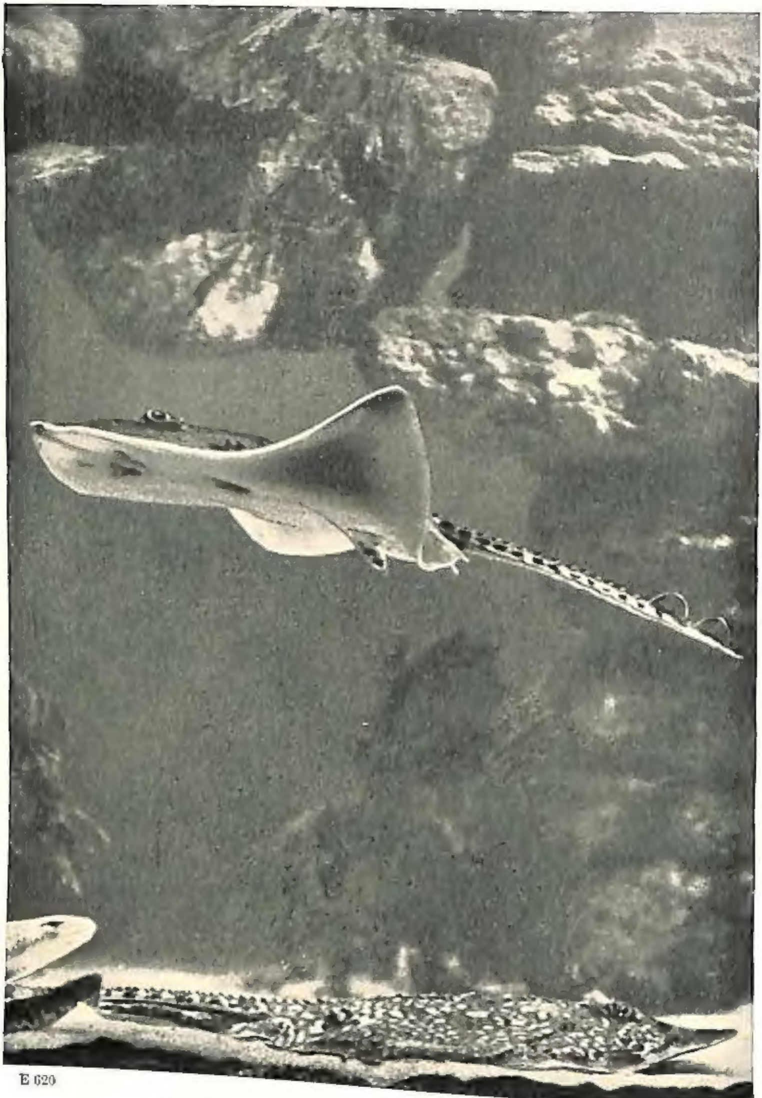

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LIFE AT THE BOTTOM OF THE SEA

These curious fish, called skate, are adapted for life on the sea-bottom

From a photograph by Neville Kingston

Frontispiece

ELEMENTARY GENERAL SCIENCE

A Course for Boys and Girls

BY

A. G. HUGHES, B.Sc., Ph.D., M.Ed.

AND

J. H. PANTON, M.A.

Book III

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Elementary General Science
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In three books

Elementary General Science
A Book for Teachers

By A. G. HUGHES, B.Sc., Ph.D., M.Ed.

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PREFACE TO TEACHERS

This is the last of a series of three books designed to provide a course in Science for boys and girls of average ability between the ages of 11 and 14.

The general plan of the course, which was explained in some detail in the preface to Book I, is a modification of the "topic method". By means of this method it is possible to present Science, not as separate subjects—physics, chemistry, biology, geology, astronomy—but as a coherent whole. In order to unify the course still further, all the work has been grouped round a single topic—The Process of Living.

As in Books I and II, we have considered our topic in its four main aspects—Breathing, Feeding, Moving, and Sensing. The course being concentric, this book is an amplification rather than a continuation of the two previous books. This arrangement necessitates frequent reference to previous work, and thus provides teachers with many suitable opportunities for revising and, if necessary, repeating work which was done in the first and second years.

Notebook summaries are given, as in the previous books, to be completed by the pupils. No help, however, is given in writing accounts of experiments, for it is suggested that, as a general rule, this type of notebook entry should now be the unaided work of the pupils. It is, of course, unnecessary to have a written record of every experiment; time is often better spent in discussing and occasionally in repeating experiments.

We acknowledge our indebtedness to all our friends and colleagues who have helped us with kindly criticism and encouragement; and particularly to Mr. E. H. Betts, B.Sc., Mr. W. E. Browett, B.Sc., Miss F. A. M. Ford, Mr. F. L. Grace, B.A., Mr. G. Lilley, M.A., Mr. R. E. Wood, M.Sc., and Mr. G. H. Woollett, M.A., all of whom have read the text at various stages, and have made many valuable suggestions.

A. G. HUGHES.

J. H. PANTON.

ISLEWORTH,
March, 1933.

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ELEMENTARY GENERAL SCIENCE

CHAPTER I

The Science of Living

You may remember that a year ago (at the beginning of Book II) we took an imaginary walk down the street, noticing the scientific facts about the things around us. Since then, we have learnt more science, and it will now be interesting to take the same walk again. We shall probably see the same sights, but this year there will be even more to notice, and more to think about than there was last year.

As we watch people walking about we know they are all breathing. They must breathe in order to get oxygen from the air for the oxidation of food. It is in this way that they get the energy they need—muscular energy to enable them to move, heat to keep them warm. The smoke from chimneys reminds us that some people are keeping warm in front of fires. The burning of coal and the oxidation of food are very similar; oxygen is being used, oxides are being formed, energy is being set free. Some rusty railings remind us of another example of oxidation—the rusting of iron.

All around us, oxygen is being taken out of the air—living plants and animals are breathing, fires of various

kinds are burning, petrol in the cylinders of engines is igniting, iron slowly but surely is rusting. We turn to look at leafy trees and plants growing in the sunlight. These we know are restoring the balance; they are feeding on carbon dioxide, storing up sunlight energy and setting oxygen free.

The food shops are more interesting than ever, for we now know more about proteins than we did last year. Proteins, we remember, are the body-building foods which contain the important element, nitrogen.

About four-fifths of the air around us is nitrogen, but neither animals nor green plants can feed on it while it is a gas. Plants feed on it in the form of nitrates which are found in the soil; they build it up with other elements into proteins. Animals, by eating these proteins, then get the nitrogen they need for their own growth.

Even the dead leaves blowing about are useful; we follow them in imagination to the soil and there we watch (still in imagination) the work of myriads of tiny living plants. These are the bacteria which cause decay, and in so doing restore nitrates to the soil. We remember that the insoluble soil particles have been formed by the gradual wearing away of rocks, and we think of the days of long ago when the granite curbstone was molten rock. This year we notice even the stones of which the road is made, and the tarred surface brings to our minds a whole host of ideas. We think of the gas-works and remember how valuable are its various by-products. Many of the brightly coloured materials in the draper's window, for example, have been dyed with colours obtained from coal-tar.

The sight of colours reminds us that sunlight is composed of ether waves of various lengths. The motor-bus looks red because its paint is absorbing the shorter ether waves and reflecting only those which cause us to see red. As the bus disappears round the corner, we begin to think of how the wheels go round; how one wheel is made to

turn another, and how the to-and-fro motion of pistons is changed into the rotary motion of wheels.

We marvel at the power of the bus, and we remember that the energy it is using has been released from petrol. We find ourselves thinking once again about the mysteries of burning. A steam roller passes by; here is another way in which the heat released by burning fuel is changed into motion energy to move heavy things along.

We see wheels almost everywhere, and we try to imagine what the street would look like if wheels had never been invented. Almost equally important are those spiral inclined planes we call screws. We do not see them as the vehicles move quickly past, but we know that hundreds of screws are holding the various parts together.

Although it has not rained for several weeks, the trees look fresh; their roots have found water in the soil. This we can understand, for we know that as the top soil dries, water from below rises in the capillary tubes between the soil particles.

It now begins to rain. Water this year means more to us than it did. We think of it as the oxide made when hydrogen burns, and we remember how an electric current can split it again into the two gases, oxygen and hydrogen. We watch the raindrops falling and we think of the mysterious and wonderful forces everywhere at work. Raindrops are pulled down to the earth by a force we call gravity; the tiny particles of water are held together in the drops by a force we call cohesion.

The shower is over and the sun is shining again. We think of the many ways in which the sun is useful: it dries our clothes; it lifts water high up in the atmosphere; it starts the winds blowing and the rivers flowing; it helps to keep living things warm; it enables plants to feed on carbon dioxide; it helps to keep us healthy; it enables us to see; it produces all the beautiful colours we enjoy. All this reminds us that the sun is our chief source of energy.

We look again at the many movements all around us—

at the movements of men and horses, of birds and insects, of motor-cars and steam rollers: we think of the many ways in which heat is being produced—by coal fires, gas fires, and oil stoves: we think of the ways in which shopkeepers and housewives are lighting up as the sun-light fades—by gas and oil lamps and perhaps in some

Fig. 1.—Using Energy released from Food

places by candles. None of these movements, none of this heat and light would be possible if sunlight energy had not been stored by green plants.

But now an electric tram goes by; an electric bell rings; here is a shop warmed by an electric radiator and lighted by electric lamps. What is electricity? You are probably ready to guess. In Chapter IV you will learn if your answer is correct. But before we start to

study electric trams and bells, we shall, in Chapters II and III, learn a little more about Breathing and Feeding, particularly about the importance of keeping air and food as fresh and clean as possible. In Chapter V we shall study some more ways in which we get news from the world around us, particularly by means of Smelling and Tasting. You will then be ready to take another walk down the same street, and you will find that everything is even still more wonderful and interesting than it appeared to-day.

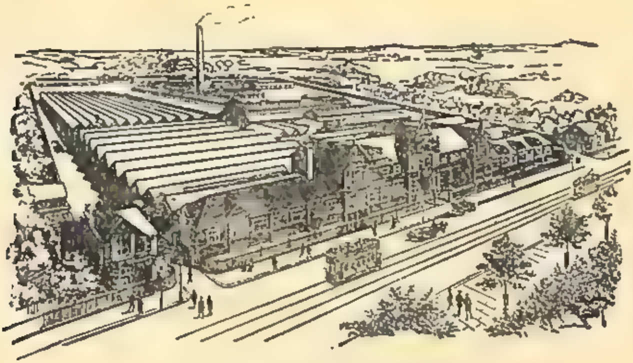


Fig. 2.—A Common Street Scene

In how many different ways is energy being used? What are the trees doing?

You will remember that in Book II we read about the work of some great men of science, for example, Newton, Priestley, Lavoisier, and Harvey. In this book we shall hear about other people famous for their scientific discoveries—Faraday, Pasteur, and Madame Curie, among others. You will find it useful to make a time-chart to help you to remember when these great people lived.

A Science Time-chart.—A convenient range is from 1000 B.C. to A.D. 2000. A broad horizontal band of paper along a corridor wall or on the wall of a classroom is suitable. Divide it into 30 equal lengths to mark the centuries. When you come across the name of a famous man of science, cut a strip of coloured

paper the correct length to represent his life, and paste it on the chart in its proper place (see fig. 3).

Book to Read.—Men who Found Out, A. Williams-Ellis (Howe).

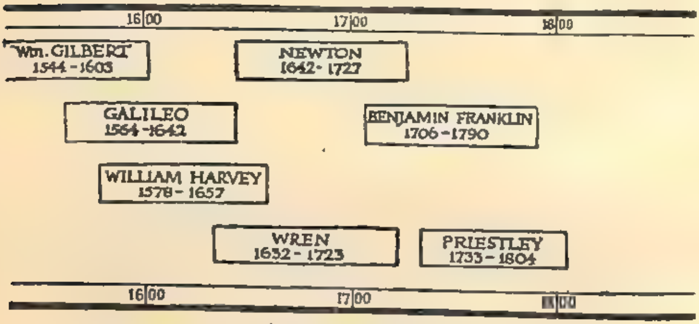


Fig 3.—Part of a Science Time Chart (in the making)

CHAPTER II

Breathing

In Book I you learned that we must breathe in order to live. In Book II you learned the reason for this; we must breathe because we need oxygen for the oxidation of food. We must now ask how it is we are able to breathe. How do we get the air into our lungs and out again?

How Lungs and Bicycle Pumps are emptied and filled.

You have breathed in and out thousands of times and probably you have never thought there was any mystery about it. You say you " draw " air in, and " blow " it out again.

It will help us to understand the problem if we first consider what happens when we draw air into a bicycle pump and then blow it out again.

1. Examine a bicycle pump. Note the four main parts: the piston-rod, the piston, the barrel, and the rubber connexion. Describe the pump and say how it works.

When you move the piston towards the rubber connexion, you push the air out. This is easy to understand; you are making the space in the barrel smaller, and the cup-shaped leather washer on the end of the piston prevents the air from escaping backwards. When you move the piston in the opposite direction, the barrel fills with air again. It does not matter whether you hold the

pump up, or down, or sideways; air always rushes in to fill the barrel. This is not so easy to understand, for although you can see you are making the space in the barrel larger, we have still to explain what makes the air rush in, upwards, downwards, sideways, in any direction.

Before we try to answer this puzzling question, let us return to the problem of breathing. Filling and emptying our lungs seems to be something like filling and emptying a bicycle pump; in both cases we have to make movements. Let us examine the movements made when we breathe.

2. Find what movements you make with various parts of your body as you breathe (*a*) in the ordinary way, (*b*) deeply.

Place your hands in turn on your chest, ribs, and abdomen.

In experiment 2, when you "blew out" air you noticed that various parts of your body moved inwards. In other words, you noticed that when you breathed out the space inside your chest became smaller. When this happens, your lungs are pressed in, so that air is pushed out just as it is pushed out of the bicycle pump when you make the space in the barrel smaller.

When you breathed in, you noticed that you moved various parts of your body outwards. This, of course, makes the space in your chest larger; it makes room for your lungs to expand. Air rushes in to fill the enlarged space, just as it rushes into a bicycle pump when, by drawing out the piston, you enlarge the space in the barrel. Air always rushes into your lungs like this when you make your chest larger, no matter what position you may be in. There is something mysterious about filling our lungs; it is the same puzzle we found when filling a bicycle pump. It seems that the air is always ready to rush in any direction to fill an empty space. Why is this? The air must in some way be forced into empty spaces. Can you think what the force is? We will later do some experiments to find out, but we must first learn a little more about breathing movements.

The Wonderful Movements we make when Breathing.

When you breathe, you make movements in order to enlarge or diminish your chest cavity, as the space inside your chest is called. The following experiment will help you to realize very clearly how breathing depends on movements.

3. Find what you do when you hold your breath.

Place your hands on your chest and ribs, and stop breathing for a moment (*a*) as you are inhaling, (*b*) as you are breathing out.

You find that "holding your breath" really means "stopping your breathing movements". These movements, like all the movements you make, are caused by muscles contracting and relaxing. But the muscles used are different from those we studied in Book I in the sections on levers. Those muscles we have to set working; the muscles used in making breathing movements are, however, always working; we have to make a special effort if we want to stop them, and then we can only do so for a few seconds at a time. (The heart is another example of a muscle of this kind, but you are unable to stop this muscle working even for a moment.)

The ribs, breastbone, and backbone form the framework of a kind of movable wall for the chest cavity. All the time we are alive, some of our wonderful non-stop muscles are moving this framework. When we are not breathing deeply, the walls move only a very little. It is in fact possible to change the size of the chest cavity without moving its walls at all. How can this be done?

4. Diminish the size of the chest cavity without moving its bony framework.

Place your hands on your chest and ribs. Take a deep breath and then breathe out, keeping your chest and ribs as still as you can. What moves?

It is possible to do experiment 4 because the chest cavity not only has movable walls; it also has a movable floor. This floor (called the diaphragm) is a large circular

muscle, and it divides the chest from the abdomen. Fig. 4 shows you how it moves when you breathe.

You have to use your muscles to expand your chest cavity in order to breathe in; when you relax them, you breathe out. Creatures which fly in the air, both birds

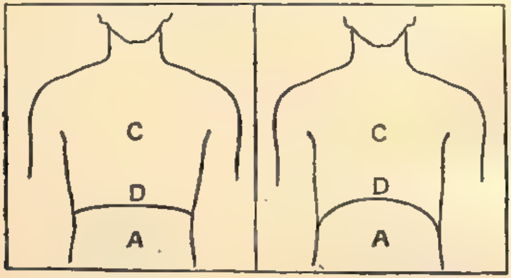


Fig. 4(*a*) Fig. 4(*b*)

C, Chest cavity; A, Abdomen; D, Diaphragm. As you breathe in, D contracts and flattens out as in fig. 4*a*: this movement makes C larger. What happens as you breathe out?

and insects, breathe in a different way. They have to contract their muscles to force air out; when they relax them, they breathe in.

The Importance of Deep Breathing.

You learned in Book II that when running races or playing vigorous games, you need large supplies of oxygen (see Book II, p. 32). To get this oxygen, you breathe deeply. You now know what this means; you fill your lungs to their fullest extent. To do this, you must make large breathing movements. This is extra work for your muscles, and they will be unable to do it unless they have been made strong by exercise (see Book I, p. 54). That is one reason why you do deep breathing exercises.

A second reason is that such exercises help you to control your breathing; this is necessary for good singing and speaking, as well as for good running and swimming.

The third and chief reason for doing deep breathing

exercises is that they help you to form the habit of breathing deeply always, even when you are not thinking about it. The following experiments will help you to see why this is important.

5. Breathe as naturally as you can, but just as you are going to breathe in, hold your breath; then, instead of inhaling, see if you can continue to breathe out.

6. Find how much air leaves your lungs at each breath as you breathe (*a*) naturally, (*b*) deeply.

Fill a large glass jar with water and invert it in a basin of water. Breathe in through your nose and out through your mouth through a glass delivery tube into the jar.

Breathe as naturally as you can; count the number of breaths you take to fill the jar with air you breathe out.

Repeat the experiment, breathing deeply.

You find from experiments 5 and 6 that you can breathe much more deeply than you generally do. You learn that in ordinary breathing, you never completely fill or empty your lungs. As a matter of fact, even in experiment 5, you were only able to force out a little more than half the air your lungs contained. Breathing does in time change all the air in your lungs, but the last trace of the air you take in at this moment will probably not have gone until you have breathed about ten more times.

A habit of deep breathing helps to keep the lungs healthy, for the more deeply you breathe, the more thoroughly you flush your lungs with fresh air.

The best deep breathing exercise is the kind you are bound to get if you take part in vigorous open-air activities. Do not forget also that, wherever you are, you can help to keep your breathing muscles working well by holding yourself in an erect position.

Notebook Exercise.

The Habit of Deep Breathing

Make lists of:

(*a*) Three reasons why this habit is beneficial.
(*b*) Open-air activities which help you to develop the habit.
(*c*) Other methods of helping to develop the habit.

Notebook Summary.

B. 1. FILLING AND EMPTYING LUNGS

(always; bones; chest cavity; diaphragm; diminishing; forced; moving; muscle; muscles; push; vary.)

We –1– air out of our lungs by –2– the size of our chest cavity. When we enlarge our –3–, our lungs expand and fresh air is –4– in to fill the extra space.

The walls of the chest cavity have a framework of –5–; the floor is a circular –6– called the –7–.

We –8– the size of our chest cavity by –9– its walls and floor inwards and outwards. These movements are made by –10– which are –11– working.

Discussion.—Artificial respiration.

Consider: How to get water out of the lungs; how to start the muscles working again.

Why Air always fills empty Spaces.

We decided (p. 8) that there must be some force which pushes air into empty spaces. It is not the force of wind, for you can quite well fill your lungs or a bicycle pump in still air. You have probably thought of the force of gravity which, as we learned in Book I (pp. 56–7), is everywhere pulling things towards the centre of the earth.

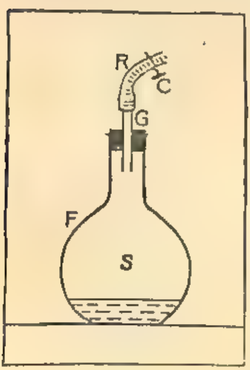


Fig. 5

Air is so light that we do not usually think of it being pulled down towards the centre of the earth. But try the following experiment:

7. Find whether the force of gravity acts on air.

F, a large flask fitted with a glass tube G and a rubber tube R which can be closed by a clip C.

Empty the space S inside the flask as completely as possible. (If necessary, refer to experiment 89, Book I, p. 101.)

When the flask is cool, counterpoise it on a balance. (See experiment 1, Book II, p. 7.) Then open the clip and wait. What has happened?

You see from experiment 7 that air has weight. This is, of course, why the atmosphere is kept in position as the earth rushes through space and rotates on its axis. If air had no weight we should very soon lose the atmosphere. It may seem surprising that the weight of air should be sufficient to keep it close to the earth; you will, however, change your views before you finish this chapter.

How much do you think the air in your classroom weighs? Having written down your guess, make a rough calculation (12 c. ft. of air weigh about 1 lb.).

Let us try to realize the effect of air having weight. You learned in Book I (p. 8) that the atmosphere is at least 45 miles high. The bottom layer of air in which we live must therefore have a heavy weight of air on top of it, pressing it down. The first effect of this is that the air is compressed so that it takes up less space than it otherwise would. We live in compressed air.

8. Find how much more you can compress the air you live in. Use a bicycle pump; take off the rubber connexion and close the end with your finger.

You find it is quite easy to compress air into a third of its original size. The air in the pump would of course still weigh the same even after it had been compressed. A cubic foot of air specially compressed as in experiment 8 would therefore weigh more than a cubic foot of ordinary air. For the same reason, a cubic foot of air near the earth's surface weighs more than a cubic foot of air at the top of a mountain. As a matter of fact, a cubic foot of air brought down from a mountain $3\frac{1}{2}$ miles high weighs only half as much as a cubic foot of ordinary air. It is not so dense; we say its density is half as much as the density of ordinary air.

The more air is compressed, the more dense it becomes; we say that its density is increased. (Refer to p. 123.) You should now think of the atmosphere as an ocean of compressed air; the farther you rise from the earth, the less compressed and therefore the less dense it is.

You will be interested to know that with special apparatus it is possible to compress and cool air so much that it becomes denser and denser until at last it becomes a liquid. If the whole atmosphere were liquefied, it would form an ocean of liquid air around the earth no more than about thirty feet deep.

We have learnt one effect of pressing air in a closed space; it becomes denser. You see another effect when you blow up a toy balloon too much; the air exerts so much pressure that the balloon bursts. As you know, the balloon is liable to burst anywhere, wherever the rubber happens to be weakest. This is because compressed air presses in all directions. To take another example, it does not matter in what part you puncture your bicycle tyre, the result is always the same; compressed air is pressing in all directions, and out it comes, upwards, downwards, sideways—wherever the puncture happens to be.

This is the second effect of pressing air in an enclosed space; the air presses in all directions.

This is exactly what the compressed air is doing all around us; the weight of air above is pressing it down, but since the air cannot escape anywhere away from the earth, it is always pressing in every direction. It does not matter whether you are out in the open air or inside a room; the room is filled with the same kind of compressed air as there is outside, and it is exerting the same pressure. If you move a book, compressed air rushes in from all directions to fill the space which the book occupied. If by moving the floor and walls of your chest cavity, you make room for your lungs to get bigger, compressed air rushes in to fill the extra space—up through your nostrils, and if your mouth and windpipe are open, down that way too. There is no need to take up any special position for breathing; you can breathe standing on your head if you like, for the compressed air in which we live is always pressing in all directions, ready to rush in any direction to fill an empty space.

Various Ways of using our Ocean of Compressed Air.

The most important way in which the pressure of the atmosphere is used, is the one we have already studied—for filling lungs. Whenever you see living creatures making breathing movements in air, you now know that they are (i) squeezing out the air they have used, and (ii) then making more room in their lungs into which fresh air is immediately forced.

Man has, however, discovered that it is convenient to use the pressure of the atmosphere in many other

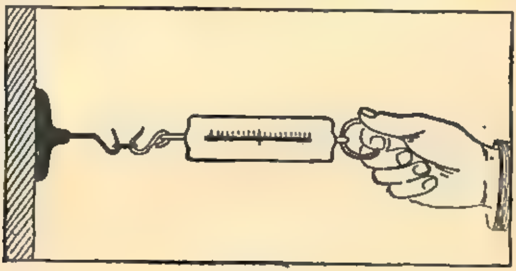


Fig. 6

ways. A very simple way is by means of a little rubber cap called a "sucker". You have probably seen this in use on shop windows.

9. Use suckers of various sizes to get some idea of how much the atmosphere presses.

Rubber suckers with cup hooks attached are convenient. If you cannot get these, make some leather suckers of various sizes with string attached. To make leather suckers work well, they should be softened by being soaked in water.

Place the suckers on some smooth flat surface, and squeeze out all the air you can from underneath them. Find with a spring balance the force required to pull them away. Pull each time at right angles to the sucker, and try the experiment when you have to pull up, down, sideways, and so on.

From experiment 9 you get some idea of the great pressure which the atmosphere exerts. It is not difficult

to lift an ordinary piece of india-rubber from the table because there is air underneath pressing up with the same force as the air on top is pressing down. But if you can get rid of the air from one side as you did with the suckers, then you find what the pressure of the atmosphere is really like.

If your suckers were all equally well made, you would find in experiment 9 that it takes more force to remove a large sucker than it does to remove a small one. This is, of course, because the larger the area, the greater is the force which the air exerts on it. Actually, the pressure of air is no less than about 15 lb. wt. on every square inch. On the top of a matchbox, for example, there is a downward force of more than 30 lb. wt. The box would, of course, collapse but for the fact that there is air inside pressing upwards with an equal force. We cannot empty a matchbox of air to see it crushed by atmospheric pressure; we can, however, empty a tin can. Let us see what happens:

10. Remove the air from a tin can by boiling a little water in it. Insert a tight-fitting cork into the neck of the can and remove it at once from the bunsen burner. Allow the can to cool.

After seeing experiment 10 you can have little doubt about the reality of atmospheric pressure (see fig. 7, p. 18). If all the air were taken out of a 1 lb. jam jar and an airtight tin lid were put on, it would be quite impossible for you to lift the lid up, for there would be a force of about 180 lb. wt. keeping it in position. In the canning and bottling industry, lids are now often kept in position in this way; it is more effective and convenient than the old-fashioned method of tying down with paper and string.

Discussions.—(*a*) In order to take off the lids from some tins and jars containing preserved food, you have to pierce the lid or prise it up a little. You hear a " fizzing " noise—what causes it? The lid is then loose—why?

(*b*) For bottling fruit, you can get jars which are closed by glass plates resting on rubber rims. Then a tin screw lid is put on over the glass plate.

(i) How do you close the jars? (ii) What is the use of the rubber rims? (iii) How do you open the jars? (iv) What is the use of the screw lids?

Note.—You will find it interesting to make a collection of tins and jars whose lids are held in position by atmospheric pressure. Notice the various devices (i) for allowing air to get in to press the lid up when you want to open it, and (ii) for preventing this being done accidentally.

Breathing at High Altitudes.

Airmen, mountaineers, and balloonists always find difficulty in breathing when they reach great heights. One reason, of course, is that the higher they get, the less is the pressure of the atmosphere, and therefore the less dense is the air. A mountaineer, 3½ miles up, would get only half as much air at each breath as he would at the foot of the mountain (see p. 13). He would have to breathe twice as fast to get the usual amount of oxygen into his lungs.

There is also another difficulty. His heart would have to work more quickly than usual in order to distribute the oxygen to his body. This is because when the pressure is low, oxygen does not combine quickly with the hæmoglobin in the blood (see Book II, p. 32).

For these reasons, airmen who intend to climb very high take with them a supply of oxygen. Mountaineers cannot conveniently carry large cylinders of oxygen; they generally have to be content without the help of a special supply of this gas. Consequently, they can only make very slow progress in high altitudes. For example, near the top of Everest the climbers had to take ten breaths for every step.

Professor Piccard, when he made his record ascents of over 10 miles in a balloon, took the precaution of sealing himself up in an aluminium sphere with a supply of oxygen. It would be impossible for any human being

to keep alive in the air found 10 miles up. It is not sufficiently compressed; it is not dense enough.

These difficulties of breathing at high altitudes remind us that we are made in such a way that we can live without discomfort in air which exerts a pressure of about 15 lb. wt. per square inch. Our bodies work best at this pressure, but they can adapt themselves to other pressures if the change from one pressure to another is gradual. This is why balloonists do not ascend very rapidly; if they did, they would suffer from nose and ear bleeding. Mountaineers, too, find that in high altitudes their health is better if they go by easy stages, allowing themselves time to get used to the decreased pressure as they go up.

Notebook Summary.

B. 2. Our Ocean of Compressed Air

(all directions; atmosphere; denser; empty; higher; light; lungs; near; square inch; upper; weight; 15 lb. wt.)

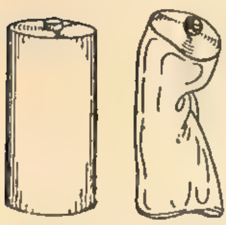


Fig. 7.—This can has been crumpled by atmospheric pressure.

Though air is –1–, it does weigh something. The –2– of the –3– layers of the atmosphere compresses the lower layers. The result is that air –4– the earth is –5– than air higher up.

Compressed air presses in –6–. This is why the air in which we live is always ready to rush into our –7– or into any –8– spaces.

The pressure of the –9– near the earth's surface is –10– on every –11–. It is less and less the –12– you go.

Breathing at Great Depths.

Have you ever thought what great pressure must be exerted on deep sea divers or on fish living in deep water? A cubic foot of water weighs 1000 oz.; it is more than 700 times as heavy as a cubic foot of air. Let us try to realize the effect of water having this weight:

Consider a column of water on a base of 1 sq. ft. Find the pressure of water on each square inch of the base if the column is 1 ft., 100 ft., 1000 ft., 1 mile deep.

You find that at a depth of 100 ft. the pressure of water is nearly 45 lb. wt. on a square inch; at the depth of a mile it is about a ton wt. per square inch. Men of science have sunk apparatus to a depth of about 3 miles in the sea. A copper tube when brought to the surface again from this depth was found to be crumpled; some glass tubes inside it had been crushed to a fine powder; blocks of wood had been compressed until they were as dense as stones. And yet there are creatures living even at these depths. In Book I, pp. 14–15, we learned that as fish breathe they take in water. Now when water is pressed, it behaves in one way like air; it presses in all directions. (You can see this when you try with your finger to stop water coming out of a hosepipe.) The great pressure under which deep-sea creatures live, therefore, does them no harm, for the pressure is equal in all directions, and the pressure of the water inside their bodies balances the pressure of the water outside. Their flesh is always very soft and watery; in fact, some deep-sea creatures have flesh which contains so much water that it is nearly transparent. In this and many other ways, they are so made that they can live at great pressures, just as other fish are adapted to live in shallower water, and just as we are adapted to live at the bottom of the air ocean.

It is interesting to notice that there is one difference between air and water when they are under pressure. Try the following experiment:

11. Fill a bicycle pump with water instead of air. Find how much you can compress the water. (Refer to experiment 8.)

Eating, Drinking, and Breathing.

Food and air meet at the back of the mouth. They have come by different routes, and they continue their journeys along different routes. Air is forced by atmospheric pressure down the windpipe into the lungs; food is forced into the stomach down the food-pipe by the

muscles of the pipe itself contracting and relaxing. Since the food-pipe is behind the windpipe, all food has to be passed over the windpipe into the food-pipe. This is what you are doing when you swallow. You can now explain what has happened when, as you say, food " goes down the wrong way ".

Drinking a glass of water or milk can be quite an interesting scientific experiment. Let us see what we can learn from it:

12. Notice carefully all you can as you drink a glass of water.

(i) Watch the surface of the water.

(ii) Notice what you do with your lips when the water touches them.

(iii) Are you breathing in or out as the water passes into your mouth?

(iv) Tip the glass until the water is touching your lips. Then try to get water into your mouth without tipping the glass any farther. What do you do?

In experiment 12 you notice at once that, as you tip the glass, the water moves; it moves so that its surface is always level, or horizontal. As you may have noticed, all liquids (even thick ones like treacle) behave in this way. If a liquid is not moving, its surface is level. If you disturb a liquid, it moves, but when it becomes still again, its surface is level once more. This is what you would expect from what you have learnt about the force of gravity. Liquids are pulled evenly towards the centre of the earth; so also is the atmosphere which presses down on the surface of liquids. Under this even pressure a liquid is bound to flow, or spread out, until all parts of its surface are the same distance from the ground, that is, until the surface is level.

13. As you fill a kettle or teapot, or watering-can, notice the level of the water in the spout.

Notice what happens as you pour out.

Notice how high the spouts are in kettles and teapots and watering-cans. Why is the top of a watering-can partly closed in?

From experiment 13 you see that a still liquid has a level surface, even if one part of the surface is separate from another part, as in a teapot. If a liquid is free to move, it does so until all parts of its surface are level.

Discussions.—(*a*) Why does water flow up pipes in our houses?

(*b*) How does a fountain work?

(*c*) Under what special conditions is the surface of a liquid curved. (Refer to Book II, p. 49.)

Notebook Exercise.—Add examples to the following list:

The Level Surface of Liquids

If a liquid is free to move, it does so until the whole of its surface is level. We make use of this property of liquids in the following ways:

In pouring out from kettles.
In supplying houses with water.

Fig 8.—What is wrong with the design of these teapots?

In experiment 12 you noticed that when drinking a glass of water, you did not merely pour the water into your mouth; you helped it in by " sucking " or " drawing in ". It is possible to drink in this way without pouring at all. Try this experiment:

14. Dip your lips into a saucer of water, and notice what you have to do in order to make water rise into your mouth.

From experiments 12 and 14 you see that sucking is very like breathing through your mouth. The difference is that instead of the atmosphere pressing more air into your mouth, it presses some liquid up. This happens because, as we learned on p. 19, when liquids are pressed they exert pressure in all directions. As you look at the level surface of any liquid, remember that, so long as air is pressing down on it, the liquid must be pressing up.

If you decrease the pressure of the atmosphere at any place on the surface, the liquid is bound to rise at that place.

A very convenient way of lifting liquids for drinking is through a straw.

15. Notice carefully all you can as you drink a glass of water through a straw. Think also what is happening.

We have now learnt that our breathing apparatus is a kind of non-stop pump. It is always in action for breathing, pumping air into and out of our lungs; it is sometimes in action for drinking, pumping liquids up into our mouths.

Discussion.—Do birds and animals use atmospheric pressure when drinking? (Notice how dogs, horses, cats, and birds drink.)

Notebook Summary.

B. 3. THE OCEAN OF PRESSED WATER

(air; atmosphere; atmospheric pressure; compressed; decreased; deeper; level; presses; square inch; surface; ton wt.; upper.)

The lower layers of water are pressed (*a*) by the weight of the –1– layers of water, and (*b*) by the weight of the –2–. Unlike –3–, water, however, can be only slightly –4–.

The pressure in water at a depth of a mile is about a –5– on every –6–. It is more and more the –7– you go.

The –8– of still water with the atmosphere pressing down on it is always –9–. But pressed water –10– upwards and in all directions. If, therefore, atmospheric pressure is –11– at any place on the surface of water, the water will rise at that place. This is why water rises into our mouths as we drink through a straw; it is pushed up by –12–.

Using our Ocean of Compressed Air to lift Liquids.

We often want to lift liquids, ink for example, which are not good to drink. It would not be safe or convenient to use our lungs, so we use an india-rubber bulb instead.

16. Examine and use a fountain-pen filler.

Why is the barrel pointed? In what way is the bulb like one of your lungs?

Explain how the filler works.

17. Take a self-filling fountain-pen to pieces and find how it works. (A cheap variety you can buy for sixpence is suitable.)
Explain how it works.
Why does the ink not run out again? (Refer to Book II, pp. 48–50.)

It is not necessary to have an elastic bag as in experiments 14–17; a piston working in a tube serves the same purpose. It is, in fact, used in some self-filling fountain-pens. These pens are filled in the same way as a syringe.

18. Take a garden syringe to pieces. Describe it and explain how it works.

The following is another method of using atmospheric pressure to lift water:

19. Use atmospheric pressure to lift water from the bowl A (fig. 9) over the side of the bowl. Allow the water then to flow down into bowl B.

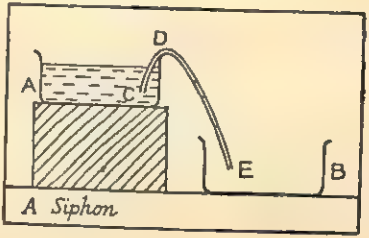


Fig. 9

CDE is a tube (narrow india-rubber tubing is the most convenient).
If CDE is full of air, the water will not be forced up CD. Why?
If CDE is full of water, what will happen (i) to the water in DE, (ii) to the water in CD? Try it.
Repeat the experiment with the tube in different positions. Try to explain the results.

Your experiments have shown you that atmospheric pressure is enough to lift up columns of liquid and to hold them up. Here is another way of showing how a column of water can be held up by atmospheric pressure:

20. Hold a tumbler T full of water upside down without letting the water run out.

See fig. 10. XY is a piece of thin cardboard.

What forces are pressing up and down at XA, at AB, and at BY?

What would happen if you held the tumbler sideways? Try it.

The upward pressure against AB is the pressure exerted by the atmosphere; this is about 15 lb. wt. per square inch. The chief downward pressure (so long as air is shut out at AB) is the pressure exerted by the water; this, as you can find by an easy calculation, is, for a tumbler, about 3 oz. wt. per square inch. It is not surprising that the cardboard stays in position.

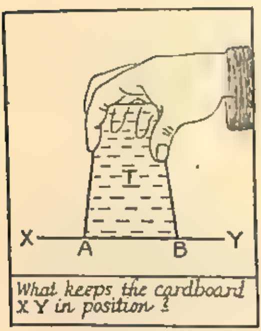


Fig. 10

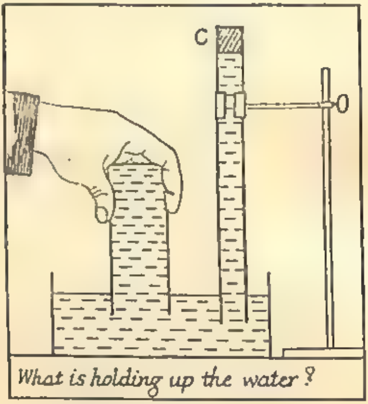


Fig. 11.—What would happen if the cork C were removed?

Another method of using atmospheric pressure to hold water in a vessel upside down is shown in fig. 11; you have already used this method in several experiments, and you know there is no need to close the mouth of the jar or tube with cardboard as in the method illustrated in fig. 10. Atmospheric pressure acts on the surface of the water in the bowl, and, as we have seen, this pressure is then exerted by the water, upwards and in all direc-

tions. In this way, atmospheric pressure holds up the water just as it did in experiment 20.

21. Use atmospheric pressure to hold up water in tubes.

With tubes of various bores, use both the method shown in fig. 10 and that shown in fig. 11.

Try the effect of opening the top end of the tube.

Discussion.—Why does ink stay in a fountain-pen filler held point downwards?

(Find what happens when you use a filler with the point broken off; then refer to Book II, pp. 48–9.)

22. Find whether atmospheric pressure is enough to hold up very long columns of water.

Use the method shown in fig. 11. Glass tubes are convenient.

You find from experiment 22 that atmospheric pressure is enough to hold up the longest column of water you can make in school. It would, however, be possible to make a column of water so long that it would exert a greater pressure than the atmosphere. Working from the facts (i) that atmospheric pressure is about 15 lb. wt. per square inch, and (ii) that 1 c. ft. of water weighs $62\frac{1}{2}$ lb., you can by calculation find how long this tube would have to be. (The answer is about 34 ft.)

Now consider the syringe again. The longest syringe you could fill would be 34 ft. You could not use it as a syringe, but it might be used for lifting water from a well. Having lifted the water up, it would be no use pushing an ordinary piston down an ordinary tube again, for that would push the water back into the well. This difficulty is overcome by two valves arranged as shown in fig. 12.

Discussion.—How does a common pump work?

(Fig. 12 will help you, but you will find it easier to understand if you can get or make a model.)

Many wells are more than 34 ft. deep. There are, for example, wells in London bored down through the chalk to depths of from 200 to 600 ft. Atmospheric pressure is not enough to lift water from these wells.

Other kinds of pumps, which make use of larger forces, have to be used.

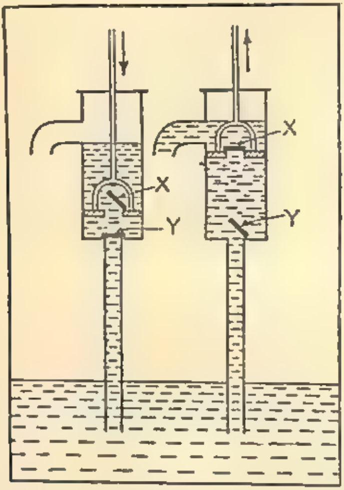


Fig 12.—How a Common Pump Works
X and Y are valves which open and close as shown

Notebook Exercise.—Add as many examples as you can to the following lists:

Ways of Using our Ocean of Compressed Air to lift Liquids

Drinking through a straw.
Filling a fountain-pen.

Other Ways of Using our Ocean of Compressed Air

For filling lungs.
For keeping lids on tins.

How Airmen know how high they are.

It is necessary for airmen to know how high they are, especially if they are flying in fog, or at night. For this purpose, they always carry an instrument called an altimeter, i.e. a height measurer. The instrument cannot, of

course, actually measure heights; it really measures the pressure of the atmosphere. As you know, the greater the height, the less this pressure is. Men of science have been able to calculate fairly exactly what the pressure is at various heights. By measuring the atmospheric pressure, it is therefore possible to tell the height fairly accurately. A better name for an altimeter would therefore be a pressure measurer. This is actually what we do call it when, for a different purpose, we use it in our houses; we call it a barometer, i.e. a weight measurer.

23. (i) Examine a barometer (aneroid type).

Remember it is really a pressure measurer. When used as an altimeter, its dial is marked in heights.

Take the barometer to the lowest place you can and notice

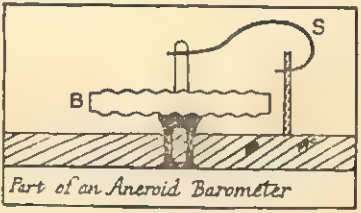


Fig. 13

where the pointer is. Then take it to the highest place you can and notice whether the pointer has moved.

N.B.—Some aneroid barometers are made so sensitive that they show the difference in pressure when they are moved from a table to the floor. An ordinary cheap kind is not nearly so sensitive; it is, however, good enough for this experiment if you take it from the cellar or ground floor to the third floor of a school building. The experiment is also worth doing on holiday in a hilly district.

(ii) Keep the barometer in one place and read it three times daily for a month. Record the results in a graph and make daily notes of the kind of weather.

Inside an aneroid barometer is an airtight steel box B out of which practically all the air has been pumped (fig. 13). The bottom of the box is fixed to the base of the instrument; the top is held out by means of a metal spring S.

As you carry the barometer higher up, the top of the box moves out slightly. This is because the higher you go, the less compressed the air is; the less pressure it therefore exerts. You can now understand how the top of the box B moves out as the airman goes up, and in again as he comes down. By an arrangement of levers and springs, these small to-and-fro movements are magnified and made to move a pointer on the dial.

Another Use for Pressure Measurers.

It is easy to understand why atmospheric pressure is different at different heights. But, as you learn from your observations in experiment 23 (ii), atmospheric pressure is not always the same when you remain at one level. A barometer kept in one place shows different readings from day to day. This is really not surprising when you remember what we have learnt about convection currents (see Book II, pp. 76–9). The atmosphere is not nearly so simple as we have been imagining it. In the first place, it is always on the move; huge quantities of heavy cold air move from polar regions and similar quantities of lighter warm air move from the tropics. Moreover, some air contains much more water vapour than other air. Now water vapour is lighter than air. Air containing much water vapour is therefore lighter than air which contains little water vapour.

You see, then, that atmospheric pressure does not depend only on altitude; it is also affected by air movements and water vapour. Speaking generally, as you may have found from your observations in experiment 23 (ii), when the pressure is increasing and high the weather is good, and vice versa. But the science of weather forecasts (meteorology) is a very difficult and complicated one; you cannot foretell with any certainty what the weather will be simply by measuring the atmospheric pressure at one place. It is necessary to know how the pressure varies over a wide area. For this purpose, barometer readings and other information are telegraphed at certain times

each day to London from ships at sea, and from 45 stations in the British Isles. It is from all this information that the weather forecasts are made. When next you hear the wireless announcer begin, " A deep depression centred over Iceland ", you can remember what a number of barometer observations have been taken before the forecast could be made.

Discussion.—Collect weather maps from a newspaper each day. Discuss the forecasts.

How Atmospheric Pressure is Measured.

When reading your barometer, you noticed that the dial was marked with figures round about 30. What do these figures mean?

To get an answer, we must examine a different kind of barometer. Atmospheric pressure was not at first measured by aneroid barometers. The word " aneroid " means " not wet ", and they were given this name because the earlier barometers were made with a liquid. The most accurate barometers are still " liquid " barometers, and there are also many of them still in use as " weather glasses ". The liquid barometer was first made by an Italian, Torricelli, in 1643; the aneroid barometer was invented many years later.

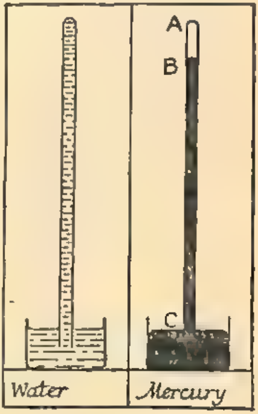


Fig. 14

24. Examine a barometer (liquid type).

Measure the length of the column of liquid it contains. Why is water not chosen as the liquid for making the barometer?

We have already seen how atmospheric pressure holds up columns of water, and we have learnt that it is enough to hold up 34 ft.

25. Make a barometer (liquid type).

(i) Fill a 3 ft. glass tube with water. Place your finger over

the open end to prevent any air from getting in, and invert the tube in a bowl of water. (Before you do it, think what will happen.)

Why is this apparatus useless as a barometer? How long would a "water" barometer have to be?

(ii) Repeat the experiment with another 3 ft. tube, using mercury instead of water. Place the apparatus on a tray so that you collect any mercury which you may spill. *N.B.*—The tube should be dry.

(Before you do the experiment, think what may happen. Mercury is more than 13 times as heavy as water. Atmospheric pressure, then, can only hold up a column of mercury less than $\frac{1}{13}$ of 34 ft. How many inches is that, approximately?)

What is the length of the column BC which is being held up by atmospheric pressure?

The space AB is called a Torricellian vacuum. It is not a perfect vacuum, for although it contains no air, it contains a small quantity of mercury vapour.

What will happen as the atmospheric pressure increases or decreases?

26. Measure three times daily the atmospheric pressure, using the barometer set up in experiment 25.

Record the results in a graph, and compare the graph with the one being made in experiment 23 (ii).

You can now understand the meaning of the figures on the dial of a barometer. When the pointer is at 30, it means that the atmospheric pressure is enough to hold up a column of mercury 30 inches high.

A column of mercury 30 inches high with a base of 1 sq. in. weighs about 15 lb. If the barometer in school at this moment points to 30, we know then that the atmospheric pressure is about 15 lb. wt. per square inch. Instead of saying it in this way, we generally find it more convenient to say how high the column of mercury is. You will notice that the width of the column does not matter. If it had a base of 2 sq. in., the mercury would weigh about 30 lb. But the atmospheric pressure on 2 sq. in. would also be about 30 lb., so that the wider column would still be held up.

In fig. 15 you see one method of making the pointer of a mercury barometer move as the mercury moves. You notice that it is not necessary to have a bowl of mercury as in experiment 25.

In the British Isles, atmospheric pressure varies from just below 28 to just above 31; on an average, it is a little less than 30. It is very seldom as high as 31; it reached that figure at Kew Observatory on 18th January, 1882, and during an exceptionally fine spell of weather in January, 1932, it was just over 31 at Cranwell (Lincolnshire) and at Chester. The record for the British Isles is 31·11 at Aberdeen on 31st January, 1902.

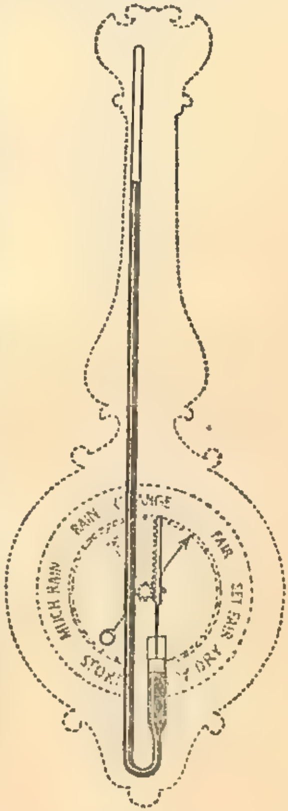


Fig. 15

As you climb up, the length of the mercury column in a barometer decreases 1 in. for about every 1000 ft. rise up to 5000 ft., and then 1 in. for about every 1100 ft. rise up to 10,000 ft. At higher altitudes, the decrease is very much less rapid. At a height of 3½ miles above sea-level, the mercury column is about 15 inches; at a height of 21 miles it would only be about ½ in.

We have learnt something of the difficulties of breathing at high altitudes. There is another curious effect of low atmospheric pressure; at the top of Mont Blanc water boils at 84° C., not at 100° C. as it does with us. The bubbles of water vapour are able to rise at this low temperature because the atmospheric pressure is so small.

Boiling water is not so hot at high altitudes as it is at sea-level. (You will remember that, in a steam-engine, water does not boil until the temperature is over 100° C.; this is because it is under very high pressure. Refer to Book II, p. 82.)

Notebook Summary.

B. 4. BAROMETERS

(aneroid; atmospheric pressure; good; high; increasing; mercury; miles; weather forecasts; 15; 28; 30; 31.)

Barometers are instruments which measure –1–. They are of two kinds, mercury and –2–.

Barometers are used for two purposes: (i) to enable climbers and aviators to know how –3– they are; (ii) to help meteorologists to make –4–.

Atmospheric pressure at sea-level is enough to hold up a column of –5– about 30 in. high. At a height of $3\frac{1}{2}$ –6–, it is only half this amount; the barometer reading would be about –7–.

On an average, the barometer reading in this country is just below –8–. Sometimes, but very rarely, it rises to –9–, and sometimes it falls below –10–. When atmospheric pressure is –11– and high, the weather is generally –12–, and vice versa.

Notebook Exercise.—Draw from memory figs. 13 and 15; write short notes to describe the two kinds of barometer and how they work.

The Importance of Fresh Air.

In Book I (pp. 19–20) and again in Book II (pp. 36–37), you learned how important it is to keep our ocean of air as clean as possible. You have also doubtless been told many times about the importance of fresh air, and you know how unpleasant it is to sit in a stuffy room. You feel drowsy and perhaps your head aches. It is impossible to work or play well unless you have a good supply of fresh air.

Your science lessons have taught you a good deal about the difference between fresh air and used air. For example, fresh air contains more oxygen and less carbon dioxide than used air. We must be careful, however, not

to jump to wrong conclusions. It is true that we need oxygen and that we could not live in carbon dioxide. But it is also true that we could, without much discomfort or harm, breathe air containing considerably less oxygen and more carbon dioxide than we find in the air in a stuffy, ill-ventilated room. You must remember too that we do not use all the oxygen we breathe in; the air we breathe out still contains about 16 per cent. It is, of course, good to breathe air well charged with oxygen and not overcharged with carbon dioxide. Fresh air, however, means more than this.

Three Rules for good Ventilation.

If you go into a room which has been shut up for a long time, you notice at once that the air is not fresh. It has not been used for breathing, but it smells stale. To keep the air in a room smelling fresh, it is necessary to keep it moving; stagnant air always has an unpleasant smell, for air contains decaying substances. Impurities are always being given off from our bodies, and they are one of the causes of stuffiness in a crowded room.

Men of science have discovered that people feel better and can work better if the air around them is always kept moving. This does not mean that we should sit in draughts, nor that the air should be blowing about violently. In a well-ventilated room, all the air should be kept gently circulating all the time. This is the first rule of ventilation.

Some rooms are hot and stuffy; others are so cold that we sit and shiver. The air in a well-ventilated room should, if possible, be kept at a steady moderate temperature, about 60° F. This is the second rule of ventilation.

In Book I we learned that the air we breathe out is warm and contains an increased amount of water vapour. If a badly ventilated room is crowded, the air becomes unpleasantly hot, and it becomes overcharged with water vapour. It is probable that the deaths in the Black Hole of Calcutta were chiefly due to these two causes—too much heat and too much water vapour. On the other hand, the

air in badly ventilated rooms heated by hot-water pipes often contains too little water vapour; the occupants then feel discomfort in the nose and throat. The third rule of ventilation is that the air should be kept neither over- nor under-charged with water vapour.

How is your Classroom Ventilated?

Discussion.—The ventilation of your classroom.

Remember the three rules: The air should be kept (i) moving, (ii) at an even temperature, about 60° F., (iii) neither too dry nor too damp.

Consider: Where fresh air comes in and where used air goes out—find out by using some smoking brown paper. Are there any parts of the room where the air might become stagnant? The advantages of different kinds of windows. The way to use sash windows. How are draughts avoided? The temperature chart. Does the room ever smell stuffy?

You find that the warm used air rises and passes out at the tops of windows, cool fresh air coming in below (refer to Book II, pp. 76–9). You see how important it is to open windows top and bottom. It is necessary not only to provide inlets for the fresh air but also to provide outlets for the used air. In order to flush the whole room with fresh air, it is a good plan to arrange a through current of air; this is best done by having windows in opposite walls. Where this is not possible, a classroom can often be flushed at playtime by allowing the wind to blow in at wide-open windows and out through the open door.

You will now find it interesting to consider the ventilation of different rooms at home. Notice what a good outlet the chimney is, but consider whether there is a draught along the floor. This will depend on the position of the door. A kitchen or scullery is often a difficult room to ventilate well. There is so much in the air to get rid of—steam from the saucepans and, if a gas-cooker is used, hot gases made by the burning of coal-gas (refer to Book II, pp. 16–17).

Some Difficulties of Ventilation.

It is very difficult to ventilate rooms perfectly especially if they are used by a large number of people. In our country, the best way of making sure that the air contains a suitable amount of water vapour is to bring in large quantities of air from outside. But the air must be let in gently, and it must be made to move evenly all over the room. In cold weather there is the extra difficulty of warming it up to the right temperature.

In dry weather, especially in towns or near roads, the outside air is often smoky or dusty. Dust and smoke may be the cause of ill-health in several ways. If present in large quantities, dust may damage the delicate linings of the nose, throat, and lungs. The greatest danger comes from disease bacteria (germs) which it carries. In ventilating large halls and underground railways, arrangements are therefore made to filter the air before it gets inside. This is not possible in ventilating small houses; the best remedy there is to prevent dust and smoke being formed outside. This is why roads are tarred (refer to Book I, pp. 19–20). A certain amount of dust always gets into houses. It is important to prevent it as far as possible from getting into our lungs. This is one reason why, when rooms are swept and dusted, the work should be done so that the dust is really collected, and not merely stirred up.

You can think out for yourselves some of the reasons why air in rooms should be kept moving, and why it should be kept neither too hot nor too cold. You will learn more reasons when, in Chapter III, we study perspiration. This study will also help you to understand one of the reasons why, from the point of view of health, the amount of water vapour in the air is important. In Chapter III we shall also learn how you can find whether air contains too much or too little water vapour.

Notebook Exercise.—Add as many examples as you can to the following list:

Ways of sweeping and dusting without stirring dust into the air

Use vacuum cleaners

Discussions.—(*a*) What is the best way of ventilating (i) a sunny room in hot weather, (ii) a room in foggy weather?

(*b*) Why is a saucer of water sometimes kept in front of a closed stove or an old-fashioned gas-fire?

(*c*) Why is it difficult to clear stuffy air from railway compartments and at the same time avoid draughts?

(*d*) Do growing plants kept in a room help to keep the air fresh, or not?

Notebook Summary.

B. 5. Ventilation

(carbon dioxide; chimney; disease; draughts; dry; dust; fresh; gently; high; impurities; moderate; moist; stagnant; 60° F.)

In a well-ventilated room:

(i) large quantities of –1– air come in from outside;

(ii) the air is kept moving –2– all over the room so that there are (*a*) no –3–, and (*b*) no places full of –4– air;

(iii) the air is kept at a –5– temperature, about –6–;

(iv) the air is neither very –7– nor very –8–;

(v) the air is clean, i.e. free from –9– and smoke.

The used air escapes (*a*) through outlets –10– up in the room, and (*b*) up the –11– especially if a fire is burning. It takes with it:

(i) –12– which is not wanted;

(ii) –13– germs;

(iii) other –14– from our bodies.

Books to Read.—The New Practical Physics, Books I and II, F. Anniss (Gregg); *Science*, Book I, Chapters V and VI, Andrade and Huxley (Blackwell); *Discoveries in Chemistry*, Chapter IX, C. R. Gibson (Blackie).

Five-minute Lectures.—In the above books you will find many interesting facts about air and water. The following topics, among others, are dealt with:

(*a*) A bicycle pump; (*b*) A bicycle valve; (*c*) Compressed air; (*d*) Liquid air; (*e*) A vacuum cleaner; (*f*) The vacuum brake; (*g*) An artesian well; (*h*) A town water supply; (*i*) A water tap; (*j*) A diving bell; (*k*) Submarines; (*l*) The hydraulic press.

CHAPTER III

Feeding

In Books I and II you learned that we need food to help us to grow, to keep us in repair, and to provide us with energy. Some of the energy is used to make muscular movements; some of it is used, in the form of heat, to keep us warm.

Keeping Ourselves Warm.

On very cold days, you often blow into your hands to warm them. You can always make air warm by passing it into and out of your lungs. This is because your body is always warm inside. If you are in good health, the temperature of your body hardly changes at all; day and night, summer and winter, it is always practically the same; about 98·4° F. This is about as warm as the air ever is during a heat wave; it is a good deal warmer than the air generally is. Your body is therefore generally making the air warmer; it is continually losing heat. The colder the outside air, the faster the body tends to lose heat.

When we are losing heat rapidly, we feel cold, and we try to put things right in one of two ways.

First, we may increase the amount of heat our body is producing. In winter we do this by eating more food (especially energy-giving fat) than we do in summer. This is like stoking up a furnace with more coal to make it hotter. We may also run about to keep ourselves warm. The oxidation of our food then takes place more quickly; this produces the extra mechanical energy required, and it also produces extra energy in the form of heat.

Second, we may decrease the amount of heat our body is losing. In winter we do this indoors by burning more fuel in our fires. We make the air warmer and as a result our bodies do not lose heat so quickly. Out of doors we wear extra clothes, especially those made of materials which are bad conductors of heat (refer to Book II, pp. 87–8).

Keeping Ourselves Cool.

Discussion.—When we are losing heat very slowly, we feel uncomfortably hot. Why is this? What can we do to put things right?

You see that we can do much to keep ourselves from getting uncomfortably hot. But in addition to all the means we decide to employ, our bodies themselves behave in special ways. In hot weather or in a hot room our sweat glands make more perspiration than usual and we sweat or perspire freely; our bodies also get flushed. All this happens automatically; we do not have to think about it.

The flushing is the result of extra blood flowing into the blood vessels near the skin. There, being exposed to the cooler air, it loses heat more rapidly than it would otherwise do. This is one of Nature's ways of keeping our bodies at the right temperature.

We learned in Book II that perspiration removes impurities from the blood. We must now try to understand why we perspire so freely in hot weather.

Perspiration, as you know, evaporates from the skin. You do not generally feel any effect because it evaporates so slowly. Try the following experiments:

27. Find the effect of allowing liquids to evaporate from the skin.

(i) Use a little of such liquids as petrol and scent; they evaporate very quickly.

(ii) Dip one hand into tepid water; keep the other hand dry. Wave both hands gently in the air. What do you feel? (This experiment works best if your hands are warm.)

In Book II you learned that heat is needed to make water boil. Now you learn from experiment 27 that heat is also required to make liquids evaporate.

When liquids evaporate from the skin, they use heat from the body and therefore make it cooler. This is how perspiration helps us in hot weather; as it evaporates, it cools us. In hot weather we usually perspire more than in cold weather; more evaporation then takes place from our skin. We therefore tend to lose more heat through evaporation in hot weather than in cold.

Perspiring is another of Nature's ways of keeping our bodies at the right temperature. At this temperature (98·4° F.) our bodies work best in every way. That is why the doctor takes our temperature; it is one means of helping him to decide upon the state of our health.

Notebook Summary.

F. 1. THE HEAT OF OUR BODIES

(evaporation; faster; heat; higher; losing; oxidation; perspire; sweat; temperature; 98·4° F.)

Most of the –1– which keeps our bodies warm is obtained by the –2– of food. We are continually –3– heat because our bodies are at a –4– temperature than the surrounding air. We also lose heat owing to the –5– of –6– from our skin. The more we –7–, the –8– we lose heat. Perspiration is therefore one means of keeping our bodies at the right –9–, viz. –10–.

Good and Bad Drying Days.

You know that puddles evaporate more quickly on some days than on others. On washing day, you often hear people say whether it is a "good drying day" or not. The rate at which water evaporates depends on several factors. A warm day is generally a better drying day than a cold day; this is because warm air can hold more water vapour than cold air. A windy day is generally better than a calm day; this is because the air near the wet clothes is moved on before it has got as much water vapour in it as it can hold.

Sometimes, however, clothes dry quickly on a cold calm day. This is because the air happens on that day to contain very little water vapour; water then evaporates quickly.

On the other hand, there are some bad drying days in summer; they are days you describe as being warm and "muggy". On these days, the air already contains almost as much water vapour as it can hold. When the air is like this, we say it is humid. When air is so humid that it can hold no more water vapour we say it is saturated. You can now understand why we call these days muggy. The weather being warm, we perspire freely. But since the air is almost saturated with water vapour, evaporation takes place slowly. Our skin therefore becomes "clammy" and we feel uncomfortable.

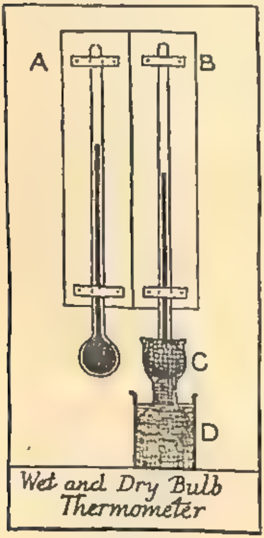


Fig. 16

There are some very simple devices for showing how humid the air is; one which you can set up in school consists of two thermometers, one with a dry bulb, the other with a wet bulb. Such an instrument is called a hygrometer, i.e. a moisture measurer.

28. Set up a wet and dry bulb hygrometer.

A and B—thermometers.

C—a muslin bag covering the bulb of one thermometer and dipping into the water in a beaker D.

Why does water rise up in the muslin? (Refer to Book II, pp. 48–50.)

Read the thermometers daily and plot the readings on squared paper. (Before reading the thermometers, disturb the air near the bulbs—why?)

Why is the reading of B below that of A? Would you expect this difference to be always the same? On what kind of day would you expect the difference to be (*a*) greatest, (*b*) least?

Notice whether the difference between the readings is always the same.

From your graph, find on which days the air was least humid.

How could you use the wet and dry bulb hygrometer to find whether the air in a room was too dry or too moist? (Refer to pp. 33–35.)

Discussions.—(*a*) Why is it bad to sit about in damp clothes?

(*b*) How does an earthenware butter-cooler work?

(*c*) What causes the formation of dew?

(*d*) Why do you feel uncomfortable if you sit in a room where the air is (i) too dry, (ii) too damp, (iii) too hot, (iv) too cold, (v) too still.

(*e*) You have probably seen a toy used for "telling what the weather is going to be". It consists of a house with a man and woman on a movable platform. How does it work?

Notebook Exercises.—(*a*) Describe the wet and dry bulb hygrometer and say what are its uses.

(*b*) Under what conditions does water evaporate quickly?

Living in Cold Water.

In Book II (p. 84) we learned that it takes more heat to raise the temperature of water than it does to raise the temperature of most other substances. That is why the sea and the swimming bath are so cool during a heat wave. Channel swimmers, however, often have to give up because they are exhausted by the coldness of the water. Human beings cannot maintain their proper body temperature (98·4° F.) if they are in cold water for a long time. Fish, however, live in water all their lives. They are so made that their bodies can work well at temperatures lower than 98·4° F., and unlike us, their body temperature changes as the temperature of their ocean changes. We say they are cold-blooded creatures. So also are amphibians such as frogs, and reptiles such as snakes. Next time you have an opportunity, notice how cold a live frog or a freshly caught fish feels in your hand.

Fish are able to live even in water which is freezing.

The freezing of water is very interesting, as the following experiments show:

29. Freeze some water, noticing the rate at which it cools.

J—a jar containing a freezing mixture M.

(A freezing mixture can be made by mixing small pieces of ice with common salt.)

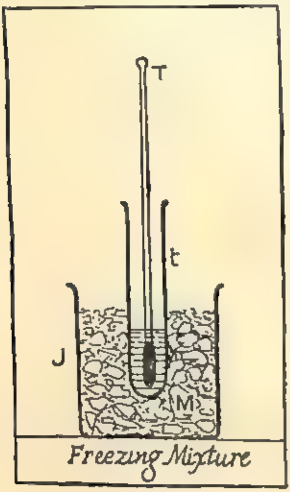


Fig. 17

t—a test-tube containing enough water to cover the bulb of the thermometer T.

Take the temperature of the water every half-minute and record the results in a graph.

30. Melt some ice, noticing the rate at which it gets warmer.

When, in experiment 29, the water has frozen solid, take out the test-tube *t* from the freezing mixture. Notice the temperature every half-minute until after the ice has all melted. Make a graph of the results.

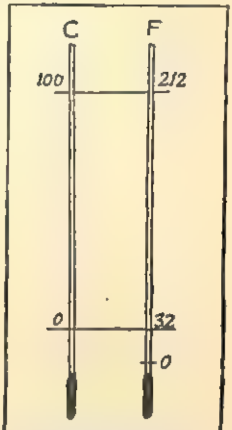
From experiments 29 and 30 you find that after water begins to freeze or ice begins to melt the temperature remains steady, or as we say, constant. This temperature is called the freezing-point of water, or the melting-point of ice.

When the ice was melting, the temperature did not rise until all the ice had melted. Heat from the air in the room was passing into the test-tube all the time, and yet the water and ice did not get any warmer. This is because heat is required to change ice into water, just as heat is required to change water into steam.

In experiment 29, heat passed from the water in the test-tube to the very cold freezing mixture in the beaker. The result, as you noticed, was that the water became cooler and cooler for a time; then the temperature remained steady. Heat was still passing away, but the water became no cooler. After a time, it changed into

ice, still at the same temperature. This teaches us that when water has been cooled to freezing-point, still more heat must be lost before it freezes.

We have learnt that there are two temperatures which are steady or fixed, viz. the temperature of melting ice and the temperature of boiling water. (Refer to Book II, p. 81.) You can see how convenient it would be when making a new thermometer (i) to put it into melting ice and mark the position of the mercury, (ii) to put it into boiling water and mark the position of the mercury again. These two marks are called the fixed points of the thermometer.



Fixed Points of Thermometers

Fig. 18

Fahrenheit, a German man of science, used a mixture of equal weights of sal-ammoniac and snow to get a fixed point. This has such a low temperature that Fahrenheit thought it was impossible to get any mixture which was colder; he therefore called the temperature 0°. He was wrong in thinking that his freezing mixture was the coldest possible, but the numbers suggested by Fahrenheit for marking the fixed points of thermometers are still used (see fig. 18).

Discussions.—(*a*) You have learnt that the freezing- and boiling-points of water are constant. Are there any conditions when water does not freeze at 32° F., and when it does not boil at 212° F.? You can devise experiments to test whether your suggestions are correct.

(*b*) How was your classroom thermometer made? What liquid does it contain? How did the manufacturer find where to put the various marks and numbers?

In Book II you learned that, as a rule, when liquids

were cooled, they contracted and became denser. Now think what would happen, according to this rule, to the water in a pond in frosty weather. The coldest water, being the most dense, would always sink to the bottom. At last, the coldest water would freeze. We might expect, then, that the pond would begin freezing at the bottom. But you know that a pond starts freezing at the top. What must happen to water before it freezes? Try this experiment:

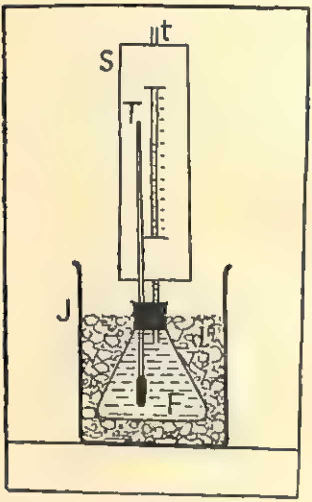


Fig. 19

31. Find why a pond starts to freeze at the top.

J—a jar containing melting ice I.

F—a flask full of water fitted with a cork through which pass a thermometer T and a tube *t*.

(Fill the flask so full that when the cork is put in water rises well up the tube *t*.)

S—a paper scale.

Notice the level of the water at the start, and then read the level every time the temperature of the water has fallen 1°. Record the results in a graph.

From experiment 31 you find that water, when cooled, starts contracting. When, however, it reaches about 39° F. (or 4° C.) it actually begins expanding and continues to do so as it cools down to freezing-point. You can now understand how it is that a pond starts to freeze at the top.

Let us try to think out what happens in a pond in frosty weather. The surface water cools first. As it cools, it contracts and becomes denser. Being heavier, it then sinks, and the lighter water, which is not so cold, is forced to the surface. This movement of water continues until the water is all cooled down to 39° F. Then, as the

surface water cools still more, it expands and becomes less dense. It therefore remains on top, a thin layer of water getting colder and colder. Its temperature falls to 32° F.; it still continues to lose heat, but it becomes no colder; then at last it expands still more and changes into ice—a thin solid layer on the surface of the pond. This layer of ice, being less dense than water, remains on top; it now prevents the water below from losing heat as quickly as it did before freezing began. The result is that the water freezes slowly so that, even in cold countries, ice is only a few feet thick. Below the ice, there is water, never colder than about 39° F. Here the cold-blooded fish can live in safety until the ice thaws.

Discussions.—(*a*) What would happen to a pond and to the fish in it if water continued contracting until it became ice?

(*b*) Why do water-pipes sometimes burst when the water in them freezes?

(*c*) What precautions can you take in a house to prevent pipes bursting in frosty weather?

(*d*) Water expands as it freezes. In what ways is this expansion useful to us?

Consider: the formation of soil from rock (refer to Book II, p. 40); the preparation of soil for sowing seeds; the dangers of icebergs.

Notebook Summary.

F. 2. THE FREEZING OF WATER

(cold; contracts; denser; expands; floats; heat; higher; less dense; surface; 32° F.)

Water freezes at –1–. As water cools, it –2– and becomes –3– until it reaches a temperature of 39° F. Then as it cools still more it –4– and becomes –5–.

Water at freezing-point (32° F.) is lighter than water at a slightly –6– temperature. It therefore –7– on the water which is not so –8–. When more –9– has been taken from this layer of water at freezing-point, it expands still more and changes into ice. Water therefore freezes slowly from the –10– downwards.

Measuring the Amount of Energy stored in Foodstuffs.

The chief energy-giving foods are those which contain starch, sugar, and fat. These are all substances which burn; this means that they combine with oxygen to form oxides. The same kind of change (another name for it is

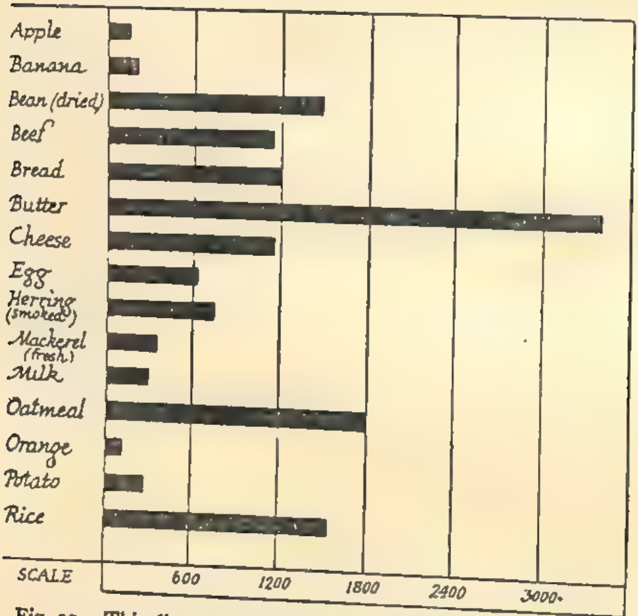


Fig. 20.—This diagram shows the number of Calories liberated by the oxidation of 1 lb. of each of the foodstuffs mentioned

oxidation) takes place in our bodies. When food combines with oxygen, energy is released. If food is burnt in air, practically all the energy is released in the form of heat. Men of science are able to measure this heat; in this way they measure the energy value of foods and fuels (see Book II, p. 85). Some of the results of their experiments are given in fig. 20.

You see at once what a large amount of energy is stored in fatty food, such as butter, and in starchy food such as oatmeal, beans, and rice. These are suitable foods for cold weather, and for people who use a great deal of energy in their daily work.

You will remember that we are always expending energy in two ways: (i) in making movements; (ii) in giving off heat. It is interesting to know that men of science have actually measured the amount of energy which people expend in a day. A carpenter expends more energy than a clerk; he therefore needs more energy-giving food. As a matter of fact, every working day a carpenter needs food which will produce about 3500 Calories; a clerk, however, only needs food which will produce about 2500 Calories. (N.B. 1 Calorie = 1000 calories.)

Discussion.—Suitable diets for (*a*) very hot, (*b*) very cold weather.

The Growth and Repair of Living Things.

In addition to energy-giving food, we need body-building food. This consists of proteins which, as we learned in Book II, are made by plants out of carbon dioxide, water and salts, chiefly nitrates. Proteins consist partly of nitrogen, the important gas which forms four-fifths of our atmosphere. They are the foods needed for the growth and repair of our bodies.

Have you ever wondered about the miracles of growth and repair? What is happening to put those extra inches on your height and those extra pounds on your weight? What happens when a cut on your finger heals up, or a broken bone joins together again? Before we can attempt to answer these questions, we must learn more about the way living things are made.

What Living Things are made of.

We have noticed that our bodies consist of various kinds of living substances, for example, muscles, bones,

nerves, blood. In Book I (p. 63) we learned that bones consist of living substance embedded in earthy salts; in Book II (p. 32) we learned that blood consists of tiny living particles carried in a liquid. As a matter of fact, all the living parts of our bodies are built up of millions of living particles very close together. They are so very tiny that you need a microscope in order to be able to see them separately.

Living plants, too, are composed of similar tiny particles, each one being enclosed by a very thin wall. These particles were first noticed by an English man of science, Robert Hooke, in 1667. Thinking they were empty little boxes, he called them cells. Since then, men of science have discovered that these little boxes are full of a very wonderful substance. Although this substance is composed chiefly of such common elements as carbon, oxygen, hydrogen, and nitrogen, no man of science has ever discovered how to make it. It is different from all other compounds, for it is alive. We call it protoplasm. The blood corpuscles are tiny living specks of protoplasm; so also are the living parts of our bones, muscles, and nerves.

All living things, both plants and animals, are built up of living cells. We know now that they are not empty boxes as Hooke thought they were. We have continued, however, to use the name which he suggested, and we call them cells. When we speak of the cells of which a plant is made, we now mean the specks of protoplasm inside the thin walls which Hooke saw. The material of which these walls are made we call cellulose; it is not alive.

The woody parts of trees consist mainly of cellulose, and, as you know, men of science have discovered how to make a great many different substances from it.

Notebook Exercise.—Add as many examples as you can to the following list:

Substances made from Cellulose

Celluloid Artificial silk

Our bodies are made of millions of cells, and there are at least fifty different kinds. Each set of cells has its own work to do: muscle cells contract; nerve cells transmit messages; the white cells in blood kill harmful bacteria. And yet every cell is composed of the same living substance, protoplasm.

A Wonderful Bit of Protoplasm.

At the bottom of ponds there lives a tiny creature which consists of one cell only; it is called an amoeba. This little animal is nothing but a tiny whitish speck of protoplasm, and yet it lives. It has no nose, no mouth, no limbs, no nerves, and yet it breathes, feeds, moves, and it appears to get news from the world outside itself.

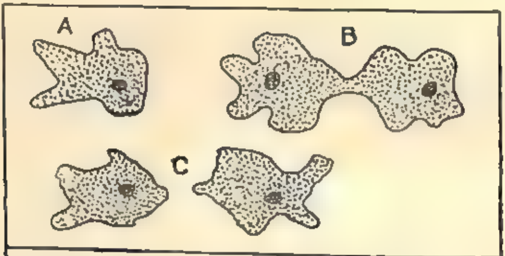
Under a microscope, it is seen to be a colourless mass of jelly. Slowly it pushes out little bulges; the protoplasm flows into these bulges and in this way the amoeba moves. We cannot see it breathing, but we know it must do so because it dies if put into airless water. It appears to be sensitive to light and heat. It will move away from particles of sand, but when it finds particles of food it closes itself round them. This food is then digested: some of it combines with oxygen and energy is released; some of it is made into new protoplasm which makes the amoeba bigger; the waste products are excreted.

It is very wonderful that a speck of jelly should be able to behave in all these different ways so like a human being. It has no brain, of course, but there is one part which corresponds to our brain. It is a tiny speck of protoplasm a little denser than the rest and is called the nucleus (i.e. the kernel). If the nucleus is removed, the amoeba no longer moves, breathes, or feeds; it is no longer sensitive, and in time it dies.

When the amoeba grows to a certain size, a very curious thing happens. It splits into two. Each half contains half the nucleus, and the two halves are able to live by themselves. There are two amoebæ where there was only one; the original amoeba has reproduced itself.

We have described this simple little animal because it gives us a picture of what is happening to many of the cells of our own bodies. New cells are being formed by the old ones splitting into two. Some of these new cells take the place of old ones which have died; they repair our bodies. Some of them are extra cells which join the old living ones; they produce growth.

You can now see why proteins are necessary for body-building. They are the foods which contain the elements required for building up fresh supplies of living protoplasm.



How one Amoeba becomes two

Fig. 21

Notebook Summary.

F. 3. WHAT LIVING THINGS ARE MADE OF

(animal; blood; carbon; cells; energy; food; grow; hydrogen; living; nitrogen; nucleus; one cell; oxygen; protoplasm; splitting; things; two.)

All living –1– are built up of –2–. A cell is a tiny mass of –3– substance called –4–. Protoplasm is composed chiefly of –5–, –6–, –7–, and –8–. The amoeba is an –9– which consists of –10–; this cell has a –11–.

Our bodies are built up of cells of various kinds, e.g. muscle cells, bone cells. They take in the oxygen and the –12– brought by the –13–. Some food is oxidized to liberate –14–. Some food is built up into new protoplasm; this is how the cells –15– bigger. New cells are formed by the old ones –16– into –17–.

More Wonders of Growth.

In Book I (pp. 33–44) we learned (i) that green plants, under the influence of sunlight, make starch out of carbon dioxide and water, (ii) that the starch is then changed into sugar and carried to all parts of the plant, (iii) that the sugar which is not wanted for growth is then stored as sugar, or starch, or oil.

The sugar needed for growth (together with salts) soaks through the thin walls of the plant cells. New protoplasm is made, and the cells grow until, like the amoeba, they divide into two. Thus the wonderful process of growth goes on. As each cell gets bigger, its thin cellulose wall is stretched. It would burst but for the fact that the cell makes extra cellulose with which it strengthens the wall. It also makes a new wall, a kind of partition to divide itself into two.

When thinking about these internal alterations, you should remember how very small the cell itself is; you need a good microscope to see it. And yet the walls are strengthened and built up by many bits of new cellulose. How extremely small each one of these bits must be! You could not distinguish it even with the help of an excellent microscope. It is the smallest bit of cellulose which can possibly be made; men of science call it a molecule. Cellulose, like starch and sugar, is made out of three elements—carbon, hydrogen, and oxygen. Since a molecule of cellulose is so extremely small, try to imagine what extremely small amounts of these elements are used in making it.

Atoms and Molecules.

In Book II (pp. 107–9) we learned that compounds are made by two or more elements combining together. Now we learn that when the compound, cellulose, is made as plants grow, it is done on an extremely small scale. When we look at a piece of cellulose, we now know that it consists of millions of very tiny particles of cellulose,

which we call molecules of cellulose. This is true of all compounds; they are all collections of molecules. For example, suppose you burn enough hydrogen to make one very small drop of water. Try to imagine what happens. As the hydrogen burns, millions of molecules of water are made; together they form the one small drop.

The molecules of compounds are, as we have said, far too tiny to be seen even with a microscope. The bits of elements which combine to form molecules are, of course, tinier still. The tiniest bit of an element which has ever been known to form part of a molecule is called an atom. We may say therefore that the water molecule consists of atoms of hydrogen and oxygen combined together. Men of science tell us that when water is made, two atoms of hydrogen are needed for every atom of oxygen. This explains why you sometimes hear people talking about H_2O when they mean water.

You sometimes see H_2O_2 on the bottles of hydrogen peroxide you buy from the chemist's shop. This reminds us that, when the same elements combine in different proportions, they may form substances which are very different in their properties. Water and hydrogen peroxide, both compounds of hydrogen and oxygen, are examples. So also are carbon dioxide and carbon monoxide (see Book II, p. 16 and p. 22); they are both compounds of carbon and oxygen.

Atoms and molecules are so small that it is almost impossible to get any real idea of their size. It has been said that if you could magnify a drop of water until it looked as big as the earth, the atoms would then look about as big as golf balls. The word "atom" means "uncuttable", that is, "indivisible". An atom was given this name because it used to be thought that it could not be divided. But you have probably read lately in the newspaper that atoms have been "split". This is true, and we shall learn something about the mysteries of "atom splitting" in Chapter V.

How Life is passed on.

We have learnt that plant cells are able to make molecules of cellulose out of molecules of carbon dioxide and molecules of water. These cellulose molecules are the tiny bricks with which a living plant-cell builds up its walls.

Inside the cell walls there is protoplasm. This, like everything else, consists of molecules made of atoms combined together. But there is a mysterious difference between protoplasm and other compounds; protoplasm is alive. Men of science can in wonderful ways make atoms combine together to make new compounds. They can, for example, make artificial silk, but they cannot make protoplasm, the marvellous substance which is alive. Living protoplasm can only be made by living protoplasm. When, for example, you see maggots wriggling about on a piece of meat, you know that they have grown from eggs laid there by some living insect. People have not always known this important fact. Aristotle (384–322 B.C.) taught that the maggots came from the dead meat, and this was believed for hundreds of years. So far as we know, until the eighteenth century everybody believed that living things could be produced from lifeless matter. This idea was not finally proved to be wrong until the nineteenth century. To-day, however, we are quite sure whenever we see anything alive, that it must have come from something else which was alive. Life is passed on from one living thing to another.

We have learnt how the amoeba passes life on. It grows and divides into two. These two amoebæ grow and divide again, making four, and so on. This gives us a very simple picture of how all living things grow.

We ourselves have grown in this way from one cell. There is, however, one important difference; the cell from which we grew was made by two special cells of different kinds joining together. As our cells multiplied, some were made for one kind of work and some for

another. Our cells, as you know, are not like the single cell of the amoeba which has to be a jack-of-all-trades.

So gradually our bodies grow. They contain a more wonderful engine and more delicate machinery than any which man can ever make. And yet they are made of atoms of such common elements as nitrogen, oxygen, carbon, hydrogen, iron, sulphur, and phosphorus.

When you were younger, you probably had Nature lessons, and you watched young plants grow from seeds, and young caterpillars and tadpoles from eggs. Perhaps

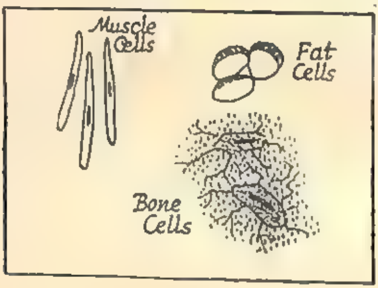


Fig. 22

you did not then realize what miracles you were watching. Now that you have learnt something about cells and molecules and atoms, you will find it interesting to repeat some of the experiments you then did. As you watch the seeds germinate and the eggs hatch out, you will be able to think about what is really happening. The living cells in the seed or in the egg, under the influence of warmth and moisture, start feeding and getting bigger. They divide, and so the miracle of growth goes on.

Most germ cells, like the cells from which we ourselves grew, are made by two special cells joining together. On most plants, the two special kinds of cells are produced by flowers. The one kind of cell is extremely small; hundreds of them are made and together they look like fine yellow dust. This is, of course, the pollen which

we find on the stamens. The other cells are larger and not so numerous; they form in the seed-box at the bottom of the pistil. Each of these cells is called an ovum (the Latin word for egg).

As you learned in Nature lessons, the pollen of one flower is carried to the pistils of other flowers in various ways—by wind, water, birds, and most important of all, by insects. The top of the pistil, called the stigma, is generally rough and sticky so that the pollen grains which fall on it stick there. They then grow down the

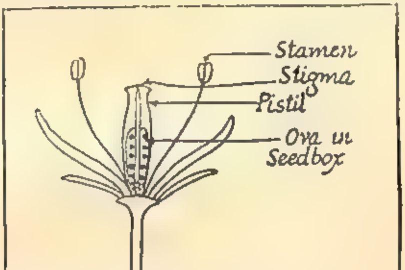


Diagram of a Flower

Fig. 23

pistil into the seed-box and one of them unites with each ovum. The ovum is then said to be fertilized; a fertilized ovum grows into a seed.

While the ovum is growing, it is usually protected by some kind of covering, peas by a pod, apple-pips by the fleshy part of the apple. These seed-boxes are then called fruits.

As you examine a seed, remember that it is alive; it grew from a germ cell which was formed by a pollen cell and an ovum cell uniting. The seed also contains food for its living cells to absorb when, on germination, it begins to grow again.

Under certain conditions, seeds can be kept alive for many years. Some lotus seeds, which had been buried for at least 120 years, were recently found to be still

alive; when put into suitable soil, which was kept warm and moist, they germinated.

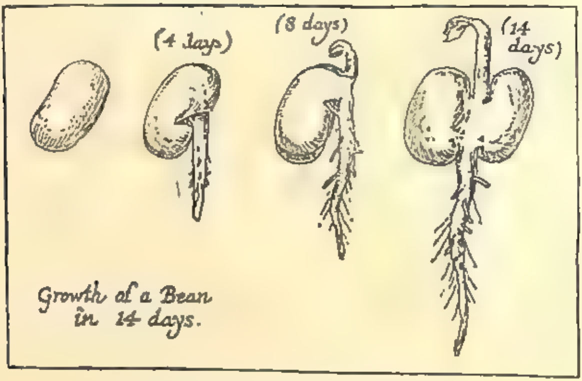


Fig. 24.—Part of a Cycle of Change

Eggs are really the seeds of living creatures. Frog spawn, for example, is a collection of eggs, all kept safe in a mass of jelly. Each tiny egg started from a fertilized

Fig. 25.—A 3-year Cycle of Change

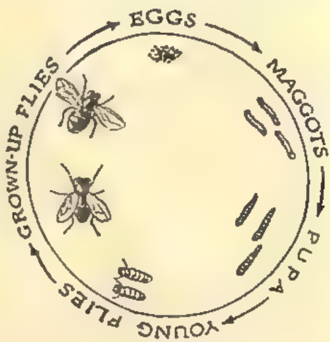


Fig. 26.—A 14-day Cycle of Change

cell, that is, a cell which was formed by two special cells uniting. Fish, also, grow from eggs. The hard roe of a herring, for example, is a collection of egg cells; the

soft roe is a collection of the cells required to fertilize the egg cells. The female herring lays her cells in a suitable place on the sea-bottom, and the male herring pours cells of the other kind over them. Those egg cells which are fertilized then begin to grow, and after from one to five weeks, tiny herrings less than one-third of an inch long are hatched out. A hen's egg, if it has been fertilized, is also a seed. The living cells look like a tiny spot on the surface of the yolk; the rest of the egg is food for the chick when it begins to grow. If the egg is kept at the right temperature (about 103° F.) and supplied with air containing moisture, the living cells grow and

Fig. 27.—Part of a Cycle of Change

divide; in three weeks the chicken is fully formed ready to break the shell and come out.

Discussions.—(*a*) Living creatures which lay eggs are able to move about and find suitable places where the eggs can develop.

Living plants which form seeds are unable to move about and find suitable places where the seeds can germinate. (Refer to Book I, pp. 50–51.)

In what different ways are seeds moved about so that they have a chance of falling in suitable places? Remember that some kind of energy is needed to move seeds.

(*b*) Why is it important for a plant to produce a great many seeds in a year?

Consider (i) the waste of seeds, and (ii) the use of seeds as food for animals.

(*c*) A cod-fish lays about 6,000,000 eggs in a year. A thrush lays from 5 to 10 eggs only. Why is there this difference?

(*d*) Why is it necessary for a bird's egg to have a hard shell? Consider how different it is from the eggs of frogs and fish.

(*e*) Why is it necessary for some flowers, e.g. apple blossom, to be brightly coloured, while other flowers, e.g. hazel catkins, may be dull in colour?

Consider also why some flowers have (*a*) honey, (*b*) scent.

Energy for Eggs and Seeds.

Since eggs and seeds contain living cells, they generally need air as well as food. The shell of a bird's egg, for example, is porous so that air can pass into it. If you hold up a hen's egg in front of a lighted candle or an electric lamp, you can see the air space inside the egg (see fig. 27). Seeds are generally able to get air from the soil, but if they are buried very deep they may have no air supply. According to the rule we learned about breathing in Books I and II, we should expect them to die, for they cannot obtain energy by the oxidation of food. But as a matter of fact they often continue to live even though they do not germinate. They are able to get the small supply of energy they need to keep themselves just alive. And they get it from food, not by oxidation but in a different way. They change sugar into alcohol. When this is done, carbon dioxide is formed and a little energy is released.

Energy is also obtained from sugar in this way by a very common plant called yeast. Set up this experiment:

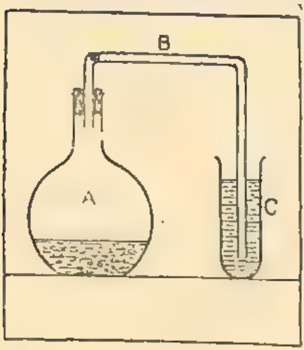


Fig. 28

32. Find how yeast changes sugar.

A—a flask containing a little yeast in a solution of grape sugar.

B—a delivery tube leading into a test-tube C full of lime-water. Put the apparatus in a warm place (75°–95° F.).

Notebook Summary.

F. 4. How Life is Passed On

(animals; Eggs; germ cell; living; living thing; ova; pollen grains; seed; union.)

Life is passed on from one –1– to another.

Many living things have grown from one –2– formed by the –3– of two special cells of different kinds.

In plants the two kinds of special cells are (i) –4– and (ii) –5–. The germ cell is formed by their union; it grows into the –6– embryo inside a –7–. –8– are the seeds of –9–

Yeast: Plants which are not Green.

You are probably surprised to learn that the yeast used in bread-making is a collection of hundreds of plants. Each yeast plant is a tiny cell; it is just as much a plant as an amoeba is an animal (see figs. 21 and 29).

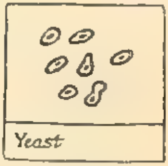


Fig. 29

In experiment 32, you noticed that the mixture began to froth and that carbon dioxide was given off. If you smell the contents of the flask, you notice a peculiar smell; it is the smell of alcohol which has been made from the sugar. The growing yeast plants use the energy which is released. The whole process is called fermentation.

The two methods of getting energy from sugar may be summarized like this:

Oxidation: Sugar and Oxygen → Carbon dioxide and Water (Energy is liberated).

Fermentation: Sugar → Carbon dioxide and Alcohol (a little Energy is liberated).

By fermentation you only release part of the energy stored in sugar. The remaining energy is still stored in the alcohol; it can be released by burning. Alcohol obtained from sugar is too expensive to use as a fuel; cheap commercial alcohol can, however, be obtained by fermenting potatoes. If our natural supplies of coal and oil are ever used up, we may have to use alcohol as

the fuel for motor-engines. If that happens, the humble yeast plant may be more important than ever.

Discussions.—(*a*) Why is yeast used in bread-making? (Refer also to discussions on cake-making, Book I, p. 11.)

(*b*) How is the alcohol in beer made?

(*c*) How is methylated spirit made?

(*d*) The uses and abuses of alcohol.

The yeast used by bakers and brewers is not the only kind of yeast plant. The wax on fruit which we call "bloom", contains yeast plants, and there is also "wild yeast" floating about with dust in the air. Remembering these facts, you can now discuss the following questions:

(*e*) How is the alcohol in wine made?

(*f*) Why do sweet foods such as jam sometimes "froth up" or "work"? Why do they then taste unpleasant?

Unlike the cells of ordinary plants, yeast plants contain none of that wonderful green substance (chlorophyll) which is able to capture the light energy of the sun. They cannot therefore feed on carbon dioxide and make starch and sugar. In this respect, they are more like animals, for they need food ready-made for them. You see this clearly if you study mushrooms, which are greenless plants belonging to the same class as yeast. The class name is fungus.

More Greenless Plants: Mushrooms.

Mushrooms will only grow in soil which contains a great deal of decaying vegetable and animal matter, for this is the food they need. Sunlight is useless to them; many of the mushrooms you see in shops have been grown in soil in dark cellars. The mushroom plant really consists of a mass of white threads which live in the soil; the mushroom we eat is rather like the fruit of the plant. If you place a mushroom head on a piece of white paper and gently tap it, you will see that a host of small brown

particles drop out. These are called spores; if they happen to settle on suitable soil they germinate and

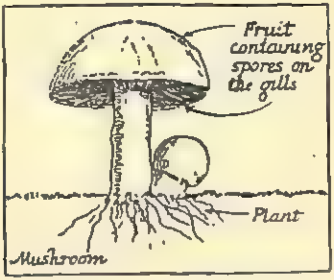


Fig. 30

grow into new mushroom plants. This is the way mushrooms and many other fungi pass life on.

What makes Food Mouldy?

You know that if you leave bread in a damp bread pan it goes mouldy. You have probably also seen other mouldy food, e.g. cheese and jam.

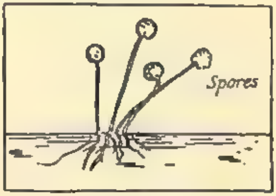


Fig. 31.—Bread Mould

33. Place some samples of food on damp blotting-paper in saucers and leave them exposed to the air.

Examine the moulds through a magnifying-glass, or, if possible, a microscope.

Discussion.—Moulds are, like mushrooms and yeast, members of the fungus class. There are many varieties; bread mould, for example, is different from cheese mould. When you find them on food, where have they come from?

Notebook Exercise.—We have only mentioned a few of the many kinds of fungi. You will find others described in larger science books. When you read about them, try to find specimens and make a list of them:

Members of the Fungus Class

mushrooms yeast

What makes Food go Bad?

Sometimes you find in the larder meat with maggots in it. These, as you know, have hatched out from eggs laid on the meat by flies (see fig. 26, p. 56). Meat is exactly the kind of ready-made protein food these creatures need.

Sometimes you find in the larder food which has gone mouldy. The moulds are greenless plants which, like

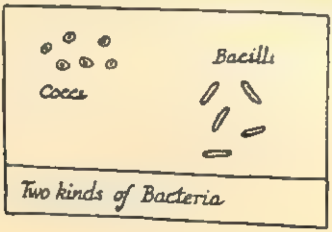


Fig. 32

animals, need ready-made food; they cannot, like green plants, feed on carbon dioxide. Moulds grow from tiny spores which were once floating in the air.

There is a third way in which food may be spoilt. You may keep the flies away from it; you may keep it from going mouldy; and yet, especially in hot weather, it may go bad. This is caused by the tiniest of all greenless plants—bacteria. They are so small that if 5000 of the largest of them were placed end to end, they would only measure an inch; many of them are smaller still.

Bacteria: the Smallest Living Things in the World.

Bacteria are to be found everywhere—in the air, in water, in milk, in our bodies. There are thousands of different kinds, and many of them are extremely useful.

In Book II (p. 46) we learned that some kinds of very useful bacteria live in the soil; there they bring about the decay of humus, and so help to keep the soil fertile.

Another useful kind lives in the stomachs of animals like sheep which eat grass; these bacteria help the animals to digest the cellulose which forms such a large part of their food. Next time you see sheep grazing, you can remember these important bacteria; without them our grasslands would be of very little use as sources of food. We ourselves cannot digest grass, or cellulose in any form, for these useful bacteria do not live in our bodies. The cellulose part of the food we eat therefore passes out of our bodies; it is no use to us as nourishment, but it serves a useful purpose in preventing constipation. Our food should therefore contain some cellulose, or "roughage" as we usually say.

Bacteria, being greenless plants, need ready-made food. When they settle on suitable material, they begin to feed on it; in so doing they change it as yeast changes sugar. This is what happens when meat goes bad; the bacteria are feeding and multiplying; the proteins are being broken up and bad-smelling gases are being made. This change is very useful if it takes place in the soil; it is a nuisance if it takes place in the larder; it is dangerous if it takes place in our blood-stream.

Bacteria were discovered by a Dutch experimenter in the seventeenth century, but it was not until the nineteenth century that their uses and dangers were discovered. The most famous man in this work was a Frenchman, Pasteur (1822–95). It was he who finally proved that decay is caused by bacteria; the story of his experiments is very interesting and well worth reading.

You may be surprised that such tiny plants can do so much and do it so quickly. The secret of their success is that they increase in numbers at a tremendous rate. Like other kinds of cells, they reproduce by growing and dividing into two. If they have plenty of food and if the temperature suits them, they can divide every half-hour. Calculate how many bacteria will grow from one bacterium in 10 hours at this rate of increase.

The temperature of blood (98·4° F.) suits them very well, and, as you know, the blood carries plenty of food. That is why it is very important to keep bacteria away from cuts and scratches. It was Lord Lister, a great English surgeon, who discovered that blood poisoning after operations was caused by bacteria from the air. He suggested the use of chemicals to kill them; these chemicals are called antiseptics. The use of antiseptics, such as iodine and carbolic acid, has saved countless lives and prevented untold suffering.

What happens when you catch Diphtheria?

Many illnesses, such as diphtheria, are caused by germs, or to use the scientific name, bacteria. When they get into the blood-stream, they increase very rapidly. They feed greedily and excrete a great deal of poisonous waste material. Very soon we feel ill; we have been attacked by a growing army of tiny living bacteria. The exact kind of illness depends on the kind of bacteria which has invaded us.

Corpuscles devouring bacteria

Fig. 33

The invading army is at once attacked by the white corpuscles of the blood (see Book II, p. 35). These corpuscles devour bacteria just as the amoeba devours particles of food. The blood also forms special chemical substances, some of which kill the bacteria, while others make the poison harmless. These

substances are called anti-bodies. After some illnesses, our blood continues to make anti-bodies for a time; while they are there, we are not very likely to have the same illness again. This explains why we are vaccinated against smallpox, or inoculated against typhoid.

Discussions.—(*a*) How vaccination or inoculation makes us immune from certain diseases.

(*b*) How rooms are disinfected.

(Some antiseptics are used as disinfectants; many disinfectants are not, however, suitable for use as antiseptics because they have a harmful effect on the body.)

Notebook Summary.

F. 5. PLANTS WHICH ARE NOT GREEN

(alcohol; anti-bodies; bacteria; carbon dioxide; energy; ferment; harmful; light energy; mushrooms; sun; useful; white; yeast.)

Plants which are not green are unable to use the –1– of the –2–; they cannot therefore feed on –3–. Like animals, they need ready-made food.

Common examples of greenless plants are: –4–, –5–, moulds, and –6–.

Yeast causes sugar to –7–; the result is that carbon dioxide and –8– are made and a little –9– is released.

Some bacteria are –10–; some are –11–.

Harmful bacteria in the blood are destroyed (*a*) by –12– corpuscles, (*b*) by special substances called –13–.

How to keep Harmful Bacteria at Bay.

You can now understand how important it is to do all we can to prevent harmful bacteria from breeding, and to keep ourselves as free as possible from them. There is not room in this book to tell you what can be done to keep harmful bacteria at bay, but the following hints may suggest subjects for discussion and further reading.

There are three main ways by which bacteria can enter our bodies: (*a*) through the skin if it is broken; (*b*) through the mouth and to a less extent through the nose when breathing; (*c*) through the mouth when feeding.

Discussions.—(*a*) How to prevent harmful bacteria from entering the body through the skin.

Consider: (i) *Cuts and scratches*—the need for cleanliness—the use of antiseptics, e.g. iodine, sunlight.

(ii) *Insect bites*—mosquitoes and malaria.

(*b*) How to prevent harmful bacteria from entering the body when we breathe.

Consider: (i) *Nose and mouth breathing*—refer to Book I, p. 13.

(ii) *Sunlight, a good disinfectant*—refer to Book II, pp. 113–4.

(iii) *Keeping the air clean*—refer to Book I, pp. 19–20—the value of mountain and sea air.

(iv) *Sneezing, coughing, and spitting.*

(*c*) How to prevent harmful bacteria from entering the body when we eat and drink.

Consider: (i) *Temperature*—practically all bacteria are killed at a temperature of 212° F.; they are not active at 32° F.—the advantages and disadvantages of boiled milk, pasteurized milk—the cooking and canning of food—refrigeration of food—when is it necessary to boil drinking water?—how and when to sterilize kitchen utensils.

(ii) *The need to keep food covered in shops and at home*—bacteria settle from the air—flies carry bacteria.

(iii) *Water at the water-works*—refer to Book I, p. 30—how bacteria are filtered out—why reservoirs are open to the air.

(iv) *Milk at the farm and shop*—T.T. and Accredited milk.

(v) *The advantages of dried food*—bacteria and moulds need moisture for growth—refer to Book I, pp. 26–27.

(vi) *Methods of preserving food* — salting — pickling — jam-making.

(vii) *Signs that food is bad*—smell and taste (refer to Chapter V)—bulging tins.

(viii) *The need for cleanliness*—dirt contains bacteria—washing before meals.

The Importance of Clean Food.

Now that you have learnt a little of what men of science teach us about harmful bacteria, you can understand very clearly how important it is to have clean food. Where there is dirt, there is danger, for dirt contains harmful bacteria. When you realize that fact, you begin to see

that cleaning and washing are really necessary for health as well as for comfort. They are two of the most important jobs in the world. Washing hands before cooking and eating is not a silly fad; it is plain common sense. It is equally important to keep houses and shops and clothes and crockery clean. And, perhaps most important of all, there is need to keep as clean as possible the ocean of air in which we live (refer to Book I, pp. 19–20, and Book II, p. 114).

For getting rid of dirt, water is, of course, extremely useful. Rain washes smoke out of the air; it removes dust from leaves and pavements. But, as you know, washing with water alone is not a quick method, especially if things are greasy. One reason is that grease will not mix with water; the water runs off leaving behind the grease with dirt adhering to it. We therefore generally use soap and water for washing.

Soap: a Useful Cleanser.

34. Find whether soap is soluble in (i) drinking water, (ii) rain water.

Refer to Book I, pp. 28–30. Try the effect (*a*) of shredding the soap, (*b*) of shaking the soap and water, (*c*) of warming the water.

35. Test whether various samples of soap are acid or alkaline.

Refer to Book II, p. 27.

36. Find the percentage weight of water in various samples of soap.

Refer to Book I, p. 26, experiment 24.

You can conveniently get rid of the water by heating the soap (shredded) in an evaporating dish in a slow oven (110° C.) for about an hour.

You find from experiment 34 that soap is soluble in water, and that if you shake a soap solution it froths, or as we say, it makes a lather. It is easier to get a lather with rain water than with drinking water. With some kinds of water, it is very difficult to get a lather. This is because the water contains salts which combine with the soap and make an insoluble scum. If you use a

great deal of soap, you can in time make all these salts combine with soap to form scum; then you are able to get a lather.

Water which lathers readily with soap is called *soft water*.

Water which requires a great deal of soap before a lather can be obtained is called *hard water*.

37. Test some samples of water for hardness.

Make a strong solution of soap in distilled water.

Take equal volumes of (i) tap water, (ii) salt or sea water, and (iii) rain water. Add to each exactly the same amount of soap solution and shake well.

Which is the softest water?

If water is very hard, it is unsuitable for washing because it forms an unpleasant scum, and because it wastes a great deal of soap. It is necessary to soften it. The best method of softening water depends on the particular kinds of salts which are making it hard. Washing soda added to some hard water softens it, but such water is not good for the skin. Water which is hard because it contains calcium bicarbonate can be softened by boiling it. The calcium bicarbonate is split up into carbon dioxide and calcium carbonate (limestone), an insoluble substance which settles as a sediment. The " fur " inside kettles is limestone formed in this way. The same substance is formed in boilers; this explains why kitchen boilers should be scraped every year or so.

In order to guard against the danger of hot-water pipes and boilers becoming blocked up with limestone, water is often softened at the water works. A common method is by adding lime. It is important, however, to add exactly the right amount of lime, for it is possible to make water hard again if too much lime be added.

If water is very soft, it is unsuitable for drinking. One reason is that it tastes flat. A second reason is that if soft water flows through lead pipes, it dissolves a little of the lead; in time, this water would give you lead poisoning.

Soap is made by boiling fat with a strong alkali, either caustic soda or caustic potash. If caustic potash is used, the soap made is the jelly-like substance we call soft soap; if caustic soda is used, the soap is hard.

38. Make some soap.

Melt about ¼ lb. of fat (any kind will do) in an iron saucepan or a large beaker, with a little water. Remove all skin. Add carefully a solution of 1 oz. of caustic soda in ¼ pint of water. Boil for about half an hour and then add a little salt. Remove the soap as it forms on the top.

Taste a little on the tip of the tongue before it dries.

In experiment 38, the alkali (caustic soda) and the fat form new compounds. One of these compounds is soap; the other is glycerine. It was glycerine which caused the sweet taste of the soap you made.

When soap is being made, the manufacturer makes sure, by adding plenty of alkali, that all the fat is changed into soap. After the soap is formed, therefore, there is always some unused alkali with it. In making the best kinds of soap, this excess of alkali is got rid of, and as you probably found in experiment 35, some kinds of soap are not alkaline. The disadvantages of using very cheap soap are that the alkali in it harms the skin and also damages delicate fabrics.

You will now find it interesting to read more about the methods of making soap, for soap-making is one of the most ancient and most important industries in the world.

You may be curious to know why it is that soap and water are so good for removing grease and dirt. There are at least two important reasons. The first is that a solution of soap and water forms thin films of soap round the particles of dirt, and makes them slide easily (refer to Book I, pp. 59–60). The result is that the dirt is loosened and is easily washed away by water. The second reason is that a solution of soap and water breaks up oil or grease into very tiny drops and prevents them from running together again; we say it forms an emulsion

of the oil. The oil is held in the liquid as separate tiny drops and can then be washed away.

When you make an emulsion of oil with soap and water, the oil is broken up, but not into such tiny particles as it is when you make a solution of oil.

39. Make an emulsion and a solution of oil.

(i) Shake up a few drops of olive oil with water in a test-tube. Why is this neither an emulsion nor a solution?

(ii) Shake up a few drops of olive oil (*a*) with soap and water, (*b*) with a solution of ammonia, (*c*) with a solution of washing soda, (*d*) with a little petrol.

Notice the difference between an emulsion and a solution.

You notice that oil is insoluble in water; it will not even mix with it. Oil is, however, soluble in petrol; we say petrol is a solvent for oil.

In Book I (pp. 28–30) we learned how important water was as a solvent. Now we learn that some substances which are insoluble in water are soluble in other liquids. It is impossible to dissolve grease in water, so we use petrol to remove grease stains from clothes (refer to Book II, p. 22). Tar is also insoluble in water, but we can dissolve it in lard.

When oil is shaken with solutions of soap, or ammonia, or washing soda, it does not dissolve. It does not, however, remain separate as it does in plain water; it mixes fairly well, forming an emulsion. You will notice that ammonia and washing soda are both alkaline; it is an interesting fact that alkaline liquids do emulsify fat. That is one reason why they are often used for washing.

Notebook Exercises.—Add examples to the following lists:

Useful solvents used in cleaning

petrol for grease
turpentine for . . .

Common solutions

camphorated oil
rubber solution

Useful emulsifiers used in washing

soap
ammonia

Common emulsions

milk
egg yolk

Notebook Summary.

F. 6. SOAP AND WATER

(boiling; drinking; emulsion; fat; glycerine; hard; lead; soap; Soft.)

If –1– is boiled with an alkali, –2– and –3– are made.

–4– water is water which lathers readily with a solution of soap.

Very –5– water is unsuitable for washing. Some water can be softened by –6–.

Very soft water is unsuitable for –7–, because it tastes flat, and it often contains –8–.

If grease is shaken up with soap and water, an –9– is formed

Discussions.—(*a*) Ways of cleaning.

Consider: use of solvents; use of emulsifiers; use of abrasives, i.e. friction cleaners (refer to Book I, p. 60); use of acids to neutralize alkalis and vice versa (refer to Book II, p. 27).

(*b*) Personal cleanliness.

Consider: skin; nose; eyes; ears; mouth; teeth; hair; nails.

(*c*) Why is methylated spirit used to remove grass stains? (Refer to Book I, p. 38, experiment 42.)

(*d*) Why are you more likely to catch infectious disease in a dirty house than in a clean one?

Books to Read.—*How Life goes on*, A. G. Whyte (Watts); *How you Work*, I. Wilson (Howe); *Science in the Home*, W. B. Little (Pitman); *Biology for Beginners*, E. J. Holmyard (Dent).

Five-minute Lectures.—The books mentioned above contain sections on the following topics:

(*a*) The amoeba; (*b*) Wasteful and careful fish; (*c*) Wonderful ways of plants; (*d*) The scattering of seeds; (*e*) Growing; (*f*) Flowerless plants; (*g*) Bacteria; (*h*) Soap; (*i*) Water softeners; (*j*) Abrasives; (*k*) Cleaning metals; (*l*) Removing stains; (*m*) "Dry" cleaning; (*n*) Science and cooking; (*o*) Cake and bread making; (*p*) Preservation of food; (*q*) The work of Pasteur.

CHAPTER IV

Moving

Wherever we may be, we can see things moving. We can also hear sounds, and these remind us that things, which perhaps we cannot see, are moving too. Then we think of the vast numbers of living creatures—in the air, on the earth, in the soil, in the sea; we think also of ships ploughing their way across the oceans, of trains thundering across continents, of aeroplanes speeding over land and sea. All these moving things are using energy, and practically all of it, as we have learnt, has come at some time from the sun in the form of light and heat.

In Books I and II we learned how living creatures move themselves and other things by means of muscular energy released by the oxidation of food. We learned how man increased the usefulness of his limbs by means of levers and wheels and inclined planes. We noticed how, by combining these three kinds of machines, he has made more and more complicated machinery; and how for many purposes this machinery is gradually taking the place of living machinery, both man's own and that of beasts of burden. Living muscles are not powerful enough to move heavy machinery quickly, so man invented ways of using the heat energy released by the oxidation of fuels. This brought us to the study of steam engines, turbines, and internal-combustion engines.

We learned that combustion in the cylinders of petrol engines is started by an electric spark. A mixture of petrol vapour and air will not ignite unless heat energy is supplied to start the combustion. The electric spark does this just as a lighted match might start an explosion.

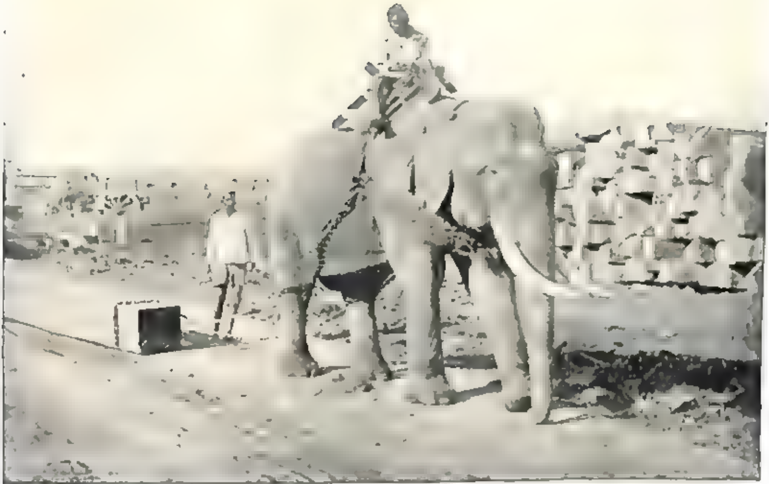


Photo. *The World's Work*

HAULING LOGS IN A BURMESE TEAK YARD

E 620

Photo. Messrs. Ransome & Company, Ltd., Newark

THE RANSOME STEAM TREE-FELLER

ENERGY IN USE: A CONTRAST

Facing p. 72

Electricity enables us to supply heat energy. It is also used to light our homes and streets, and, as you know, it can move trams and trains. Light, heat, and motion are all forms of energy; it is quite clear that electricity is another form of energy.

Notebook Exercise.—Add as many examples as you can to the following lists:

Ways in which Electricity is used

(*a*) *To move things*	(*b*) *To produce heat*	(*c*) *To produce light*
electric trams	electric radiators	electric lamps

Electricity is changed into light and heat in sparking plugs and electric lamps; it is changed into heat in electric radiators, irons, and cookers; it can be used to move all kinds of things—fans, trams, and trains. In the electric bell it moves a clapper; electric energy is in this way changed into sound, another form of energy. In order to help us to understand how this is done, and to find out some more wonderful facts about electricity, we will do some experiments with an electric bell.

Making an Electric Bell Ring.

40. Fit up an electric bell as shown in fig. 34.

A — copper wire covered with cotton.

B — an electric bell.

CD—a battery of two dry cells.

Disconnect any one of the terminals; then touch the terminal with the bare end of the wire.

Repeat with other terminals.

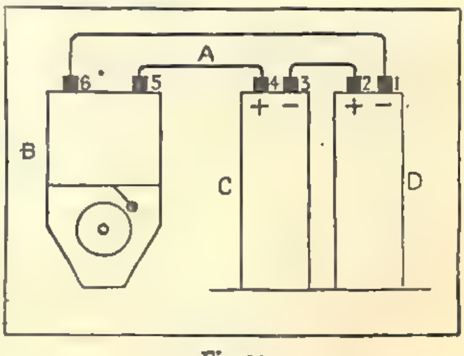


Fig. 34

You find that the bell rings as long as the terminals are joined up as in fig. 34. If, however, any terminal is

disconnected, the bell stops ringing; this is because the electric current will not flow unless the battery terminals are joined up. You can now understand why you can keep an electric torch battery in good working order for

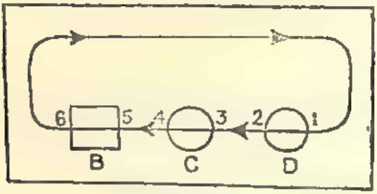


Fig. 35

a long time if you only use it occasionally for short flashes. There must be a complete path outside the battery from terminal to terminal before the electric current will flow; we say there must be a complete circuit. The circuit for experiment 40 is shown in fig. 35, which is a diagram of the apparatus used. Trace out the path of the electricity from terminal 1 through the bell and the two cells.

How Electricity is Switched On.

41. Switch the light on and off in an electric torch. Find out how the circuit is changed as you move the switch to and fro.

42. Collect some electric-light switches of different types and find out how they work.

(If you examine a switch in an electric-light or "power" circuit, you should first switch off the current at the main.)

From experiments 41 and 42 you learn that when you switch on the electricity you close a gap in the circuit.

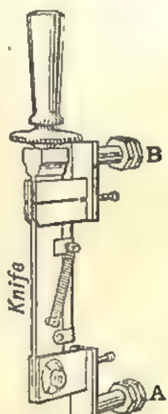


Fig. 36.—One kind of Electric Switch.

Conductors and Insulators.

The circuits round which electricity flows in houses are, as you know, made of metal; the wires are generally

copper, and the metal parts of the switches are most often made of brass. Copper and brass are good conductors of electricity; air, as you noticed in experiments 40–42, is not.

43. Test whether substances are good or bad conductors of electricity.

Fit up the apparatus as in fig. 37. (Or you can use the apparatus of experiment 40.)

A—pocket-lamp electric battery.

B—pocket-lamp bulb.

C—copper wire leading from terminal D and wound round the thread of the bulb at E.

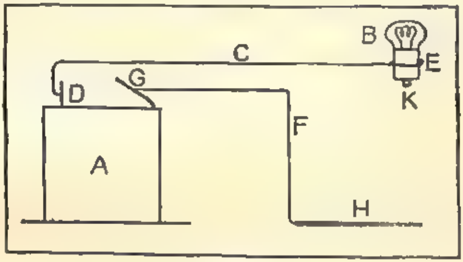


Fig. 37

F—copper wire leading from terminal G connected with H. (For H use various substances, e.g. wood, vulcanite, paper, tin, iron, a silver coin, rubber, earthenware, a rod of carbon.)

Touch K on H.

Arrange the substances in two lists: (*a*) good conductors, (*b*) bad conductors.

In experiment 43 the metals and the rod of carbon conducted electricity well, but you could not get a light when you used the other substances in the circuit. You cannot be sure, however, that no electricity was flowing through these substances—why?

Some substances—for example, vulcanite, rubber, and earthenware—are bad conductors of electricity. So badly do some of them conduct electricity that they are often used to stop it flowing. Substances used for this purpose are called insulators.

Wire used for carrying electricity is often covered with cotton or rubber; such wire is called insulated wire. One reason for using it is to prevent the electricity taking short cuts, as it would if two bare wires in a circuit happened to touch. The handles of electric vacuum cleaners are generally made of vulcanite, a very good insulator. This is done for safety because the human body is a conductor and it is dangerous to pass strong currents through it.

In Book II (pp. 17–18) you learned that water containing a little acid is a conductor of electricity. Pure water is a bad conductor, but ordinary water is a fairly good one. This is because it contains dissolved salts. When handling electrical apparatus through which strong currents are flowing, it is safer therefore to do so with dry hands than with wet ones. Insulators too should be kept dry.

Discussions.—(*a*) How is the circuit completed in an electric torch?

(*b*) How are we protected from "shocks" when using electrical machines?

(Examine, for example, a vacuum cleaner, an electric iron, fan, radiator.)

(*c*) Why do workmen on electrified railways use rubber gloves and mats?

(*d*) Is the earth a good or a bad conductor of electricity?

(*e*) How is electricity conveyed to electric trams and trains as they move along?

(*f*) How is electricity brought into our homes and schools?

(*g*) Rubber gloves are included in some first-aid outfits. Why?

How an Electric Bell Works.

44. Examine an electric bell and its circuit.

Fit up apparatus as in experiment 40, but put a bell push in the circuit.

Take off the box which covers the "works" of the bell (see fig. 38).

When you switch on the current, you see that the clapper C moves rapidly to and fro, and rings the bell B. When the current is off, you notice that C is held back

by a spring S which touches an adjustable screw A; it takes some force to move C with your finger against the pull of S so as to make it strike B. And yet an electric current does it. How can electricity produce force? When thinking about this puzzle, notice the piece of iron D which is attached to C.

The following experiment will help you to solve the puzzle:

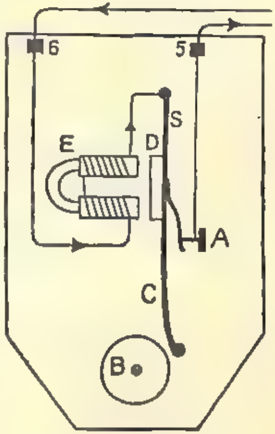


Fig. 38

45. Wind about 12 in. of very thin insulated copper wire round a piece of soft iron XY as in fig. 39. (An iron nail will do.)

Connect up the ends of the wire to a battery B, and put a switch S in the circuit.

Place some small iron nails or some iron filings very near the ends XY of the iron bar and switch on the current. Then switch the curent off.

Repeat, switching the current on and off quickly.

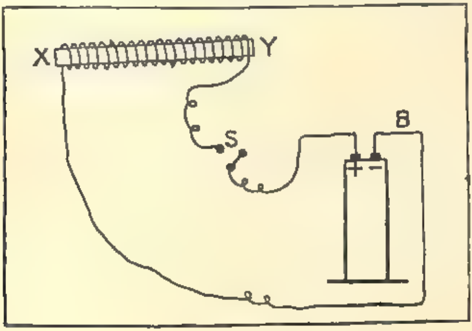


Fig. 39

In experiment 45, as long as the current was flowing, the iron bar was a magnet and attracted iron filings to itself. When the current was switched off, practically

all the iron filings previously attached to it dropped off again; the bar was no longer a magnet of any strength.

Magnets made by electricity in this way are called electro-magnets, and they are often used for moving things. An electro-magnet is, for example, the secret of the working of an electric bell. Electro-magnets are also used in electric motors, telephones, loud-speakers, electric clocks, and in many other electrical appliances. In the picture opposite p. 88 you see another example of an electro-magnet; this one is so powerful that it can hold pieces of iron weighing several tons.

Discussions.—(*a*) How does an electric bell work? Trace out the circuit in fig. 38. What happens to the circuit when D is attracted to E? What then happens to E? And to D? Why is there an adjustable screw at A?

(*b*) If an electric bell will not ring, what are the possible causes of failure?

Notebook Exercise.—Draw a diagram of an electric bell and explain as briefly as possible how it works.

How Magnets are made.

You have probably often played with magnets, either bar magnets or magnets made in the shape of horseshoes. You know that they will attract iron or steel, but they will not attract other common metals such as aluminium or copper; nor will they attract non-metals such as wood or paper. Unlike the electro-magnet in the electric bell, the magnets you play with are magnets all the time; we call them permanent magnets. How are they made?

46. Use electricity to make a permanent magnet.

Repeat experiment 45, using a steel knitting needle instead of a soft iron nail.

You find from experiment 46 that steel, like soft iron, is magnetized by an electric current; unlike soft iron, however, it does not lose so much of its magnetism when the current is switched off. Permanent magnets are made from steel in this way by using strong currents.

Although magnets may be called permanent, this does not mean that they can never lose their magnetism. If they are knocked about or made very hot they do, as a matter of fact, become demagnetized.

47. Demagnetize the magnet made in experiment 46.

It is only a little more than a hundred years since Sturgeon, a Lancashire shoemaker, discovered that magnets could be made by electricity. Magnets were known, however, as early as the fifth century B.C. They were then made of lumps of black stone first found in the ground near a town Magnes in Asia Minor. This stone is an oxide of iron (now called magnetite); it behaves like a magnet.

Magnets have for centuries been used by travellers to help them to find their way about. Magnetite was first used for that purpose, and it was therefore called lodestone, i.e. leading stone. How do magnets "lead" or guide travellers?

48. Examine a suspended compass needle.

It is a permanent magnet. How could you test this?

Push one end of the needle sideways and notice in what position it comes to rest. Try to make it stop in another position.

Mark one end with white chalk: move this end through 180° and then release it.

You find that a compass needle always takes up the same position when it is free to move. Any bar magnet would do the same if it were free to move. In England a compass needle points roughly north and south, though not exactly so. The ends of a magnet are called poles, and the end which points north is called the north-seeking pole, or for short the north pole; the other end is called the south pole.

In order to move a suspended magnet from its fixed position some force must be used. You can, for example, push or pull it with your finger. The following experiments show you other ways in which a magnet can be moved:

49. Try the effect of bringing a piece of unmagnetized iron or steel near (i) the N pole, (ii) the S pole of a compass needle.

50. Try the effect of one magnet on another.

(i) Bring the N pole of a bar magnet near the N pole of a compass needle.

(ii) Bring the N pole of a bar magnet near the S pole of a compass needle.

(iii) Bring the S pole of a bar magnet near the N pole of a compass needle.

(iv) Bring the S pole of a bar magnet near the S pole of a compass needle.

Tabulate your results like this:

N pole attracts . . .	N pole repels . . .
S pole attracts . . .	S pole repels . . .

From experiment 50 we learn the important rule which is generally stated thus:

Like poles repel each other: unlike poles attract.

You can now guess why a compass needle always points N—S. The earth itself must, for some mysterious reason, be a huge magnet.

Discussion.—Where is the N pole of the largest magnet you have heard of?

From experiment 49 we learn that there is a force of attraction between a piece of unmagnetized iron and either pole of a compass needle. When you put a magnet near iron filings you observe the same fact; the filings are attracted by both poles. In the space near a magnet a special magnetic force is acting; this space is known as the field of force. The earth's magnetic field extends all over the surface of the world, but the field of force of an ordinary magnet is, of course, very much smaller. If a piece of iron is brought into the field of force, the iron and the magnet tend to move towards each other. If the magnet is fixed and the force is strong enough, the iron moves to the magnet; if the iron is fixed and the magnet is free to move, the magnet moves towards the iron. Sometimes they both move.

51. Test whether a given piece of steel is a magnet or not. (You will be given a piece of steel and a compass needle. Think what you must do before you begin.)

Magnets used to be made in the following way without using electricity:

52. Use one magnet to make another magnet.
Find a piece of steel spring, or a steel needle which is unmagnetized.
Stroke it with the N pole of a bar magnet. Begin at A and stroke firmly to B; lift the magnet and stroke AB in the same

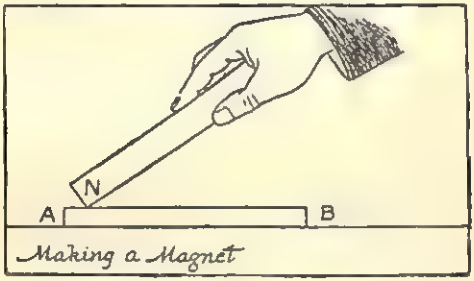


Fig. 40

direction again. Repeat the action several times. (Stroke in one direction only, not to and fro.)
Test whether the steel is now a magnet, and find which is the N pole.
Repeat the experiment with another piece of unmagnetized steel, using the S pole of the bar magnet.

53. Find which is the N pole of an electro-magnet.
Use a compass needle and the same apparatus as in experiment 45, fig. 39.
Put a chalk mark on the N pole.
Now change over the wires connecting the terminals of the battery.
Test whether the marked end is now a N pole.

54. Repeat experiment 53 with a coil of wire without any core of iron or steel.

Notebook Exercise.—Write a short essay on "How Magnets are Made".

Why Terminals are marked + and —.

You found from experiment 53 that it makes a difference to an electro-magnet when you change over the wires joined to the terminals of the battery in the circuit. This is because when you change over the wires, you reverse the direction in which the current is flowing. If one end of the iron is a N pole, and you then make the current flow round in the opposite direction, that end becomes a S pole (see fig. 41).

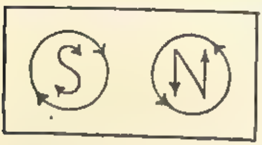


Fig. 41.—As you look into the S pole of the coil, the current is flowing in a clockwise direction. If you reverse the direction of the current (as in experiment 53) the poles are changed. Notice how the arrows on S and N help you to remember this rule.

Although we talk about a current flowing in a wire, you must not think that it is really like water flowing in a pipe. The wire is not hollow. Yet in some ways the flow of electricity is like the flow of water.

Water flows along pipes from a high level to a low level. An electric current "flows" along wires from one terminal of a battery to the other. These terminals are not different in height; in fact, apart from the fact that they are marked + and —, you cannot see that there is any difference between them. But the results of experiment 53 proved to you that there must be a difference. The terminals are different in a mysterious way which you cannot now understand; men of science call it a difference in potential. The + terminal, they say, is at a higher potential than the — terminal. When terminals at different potentials are joined by a wire, a current of electricity is set in motion in the wire; we say that the current flows from the + terminal to the — terminal.

For many kinds of electrical apparatus, bells, irons, and vacuum cleaners for example, it does not matter which way the current flows: you therefore put in the plug just as you happen to pick it up. In wireless apparatus,

it is often important to send the current through the circuit in one direction only; that is why you have plugs which will only fit if inserted in the right way. For the same reason, the terminals of batteries are plainly marked: +, −; or they are coloured: red, blue.

Difference in potential is measured in volts by an instrument called a voltmeter. An accumulator supplies current at a voltage of about 2; in wireless you call this a "low-tension" current. In order to get a higher voltage from accumulators or dry cells we have to connect several of them together as we did in experiment 40 (see fig. 34, p. 73). Two accumulators connected in this way give a voltage of about 4, and so on. You can now see why a "high-tension" battery is made of a large number of small cells joined together.

The voltage of current supplied to houses is generally about 200, but this current is set moving, not by batteries but by dynamos. We shall learn about dynamos later in this chapter.

Discussion.—An electric lamp for household use may be marked 240V; a lamp for a motor headlight, 6V.

What do these markings mean and why are they different?

Electrical apparatus is made to be worked by current at a certain voltage; and this is generally marked on it, e.g. 240V. A vacuum cleaner suitable for use in London (voltage 240) would not work in some other towns where the current is supplied at a voltage of only 110. This current is not at a high enough "tension" or "pressure"; it would not send enough electricity through the circuit to turn the fan. Apparatus made for high-voltage current will not work with low voltage; insufficient electricity flows through it.

If, on the other hand, a high-voltage current is passed through a low-voltage vacuum cleaner, too much electricity flows, the fan revolves too fast, and the apparatus soon wears out. It might generate so much heat that the cleaner would be put out of action at once.

Notebook Summary.

M. 1. A Current of Electricity

(circuit; difference; electricity; high; insufficient; low; low potential; potential; voltage; volts.)

Electricity flows in a –1– from a point at a high electrical –2– to a point at a –3–. The –4– in potential (which is in some ways like a difference in pressure) is measured in –5–.

The proper –6– for electrical apparatus is generally marked on it. If a –7– voltage current is sent through apparatus made for a –8– voltage current, too much –9– flows and the apparatus may be damaged. A low-voltage current cannot work apparatus made for a high-voltage current; this is because –10– electricity flows.

How Electricity moves Things Round and Round.

We have learnt how electricity can be used to make magnets. We have also learnt that magnets can move other magnets and pieces of iron.

It is by using these magnetic forces that electricity can be made to move things to and fro. All you need to do is to arrange for the electricity to make an electro-magnet and then have a piece of iron near it.

In the electric bell, the magnet is fixed and the iron is free; the iron then moves to the magnet.

In the electric brake on a tram-car, the iron rail is fixed in the roadway; it is the magnet which is free, so the magnet moves to the iron and grips the rail (see p. 80).

These are all examples of to and fro motion. How does electricity turn axles round and round to drive fans in vacuum cleaners and wheels in tram-cars? As perhaps you know, it is done by a machine called an electric-motor. This has nothing to do with motor-cars, for as we learned in Book II, these are generally driven by petrol engines.

If you examine an electric motor you will find that it consists of coils of insulated copper wire between the poles of a magnet; these coils are generally wound on cores of soft iron. The motor is worked by sending a current

of electricity through the coils. The following experiments will help you to understand what happens when a current of electricity is sent through a coil of wire near a magnet.

55. Find the effect upon a movable magnet of a wire through which a current is flowing. (A compass needle is the most convenient kind of movable magnet to use.)

Join the terminals of a battery to a long wire and hold part of the wire parallel to a compass needle (i) above it, (ii) below it.

You find that a force is exerted between the compass needle and the wire carrying a current. The needle, i.e.

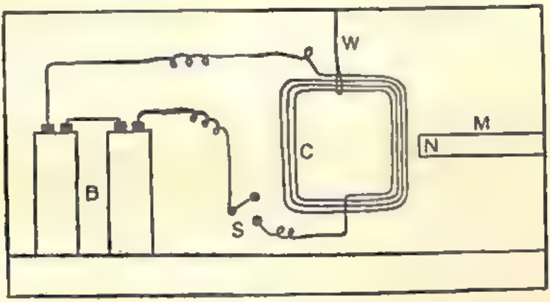


Fig. 42

the magnet, is free to move, and it does so. This fact was discovered by a Danish man of science, Oersted, in 1819.

What will happen if the wire is free to move while the magnet is fixed? Try this experiment:

56. Find the effect of a fixed magnet on a coil of wire through which a current is flowing.

Fit up the apparatus as in fig. 42.

C is a coil of thin insulated copper wire of many turns joined in a circuit with a battery B and a switch S. The coil should be suspended by a very thin thread or wire W near a magnet M.

Switch on the current and watch the coil carefully.

You find that, as in experiment 55, a force is exerted between the "live" wire and the magnet. In this

experiment, as the coil is free, it moves. This is what you would expect, for we learned from experiment 54 (p. 81) that a coil of wire was a magnet with N and S poles when a current of electricity was flowing in it.

This is what happens in an electric motor. The coil, or armature as it is called, is free to move between the poles of a magnet. When the current is sent through it, the coil becomes a magnet and its poles are repelled and attracted by the poles of the fixed magnet; the result is that it turns. There are two difficulties; perhaps you have already thought of them.

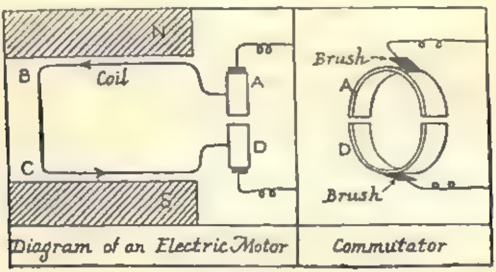


Fig. 43

First, when the coil turns round and round, what happens to the connecting wires which bring the current to it? Obviously, they cannot be joined on to the coil as they were in experiment 56. It is not necessary that they should be, for as you learned in experiment 40, the current can flow if wires just touch. Actually, the ends of the coil are attached to a ring which turns round with the coil; this ring picks up the current from the "live" wires. In order to make good contact, the ends of the live wires are generally joined to pieces of carbon or to pads of copper gauze (called brushes); these brushes press against the ring as it turns (see fig. 43).

Second, why does the coil turn completely round and round? In experiment 56, the coil turned so far and then stopped. If you look at fig. 43 you will see that the

ring is in two parts. In the position shown, let us suppose the current is flowing in the direction ABCD; this will cause the coil to start turning. But what will happen when the coil and ring have turned half-way round? The current will then flow in the opposite direction DCBA. The effect of reversing the current flowing through a coil is to change its N pole to S and vice versa (see fig. 41, p. 82). You see, then, that the armature of a simple motor is really a magnet whose poles are changing each time it turns half-way round. The result is that the armature is kept moving round and round by the repulsion and attraction of the fixed magnet.

The split ring which reverses the current so simply is called the commutator.

You can understand that if there was only a single turn of wire in the armature, it would turn jerkily and without much force. In electric motors, the armature is therefore made of many coils of wire, and the commutator is made of as many parts as there are coils in the armature. You can understand this best by examining an actual motor. The magnet between which the armature rotates is a strong one; it is generally an electro-magnet.

Notebook Summary.

M. 2. ELECTRIC MOTORS

(electric current; fixed; force; magnet; movable; move; vice versa; wire.)

If an –1– is flowing through a wire near a –2–, a –3– is exerted between the –4– and the magnet. If the magnet is free to –5–, it does so, and –6–.

In an electric motor, the magnet is –7– and the wire is –8–.

Notebook Exercise.—Draw fig. 43 and describe briefly how an electric motor works.

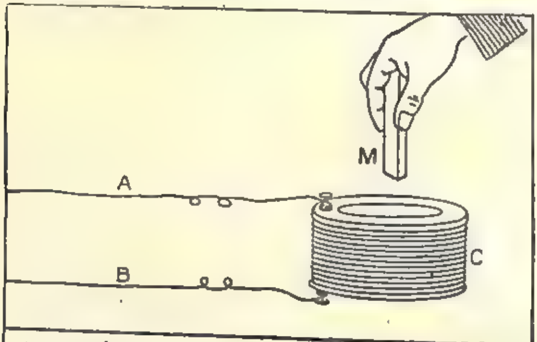
How a Dynamo Works.

The electricity supplied for heating and lighting, for working vacuum cleaners and for driving electric trams

and trains is, as you know, generated at power stations by means of dynamos.

We have learnt that, by means of an electric motor, a current of electricity can be used to produce movement. A dynamo is a machine which works in the reverse way; it is used to convert movement into a current of electricity. These facts may be summarized like this:

CURRENT → MOTOR → MOVEMENT
MOVEMENT → DYNAMO → CURRENT



A Faraday Experiment 1831

Fig. 44

It is just over 100 years since Faraday (in 1831), after many experiments, first produced a current of electricity by moving; he moved a magnet in a coil of wire. The current made in this way is, however, a very feeble one; it would not ring a bell or light a lamp, nor would it be strong enough to move an ordinary compass needle. Faraday used an instrument, called a galvanometer, in order to detect the feeble currents he was able to make in his early experiments. The simplest kind of galvanometer is a delicately poised compass needle at the centre of a coil of wire.

Faraday's experiment in which he first made a current of electricity by moving a magnet was really the beginning

E 620

Witton Kramer Co., Birmingham

A STRONG ELECTRO-MAGNET

This magnet is used for handling pig-iron; it is 42 inches in diameter and can lift several tons

Facing p. 88

of dynamos and power stations. It is so important that we ought to repeat it:

57. Find the effect of moving a magnet in a coil of wire.
In fig. 44, ACB is a coil of insulated wire with a great many turns connected by long wires A and B to a sensitive galvanometer. (N.B.—The galvanometer must be so far away that it is not affected by the magnet M.)

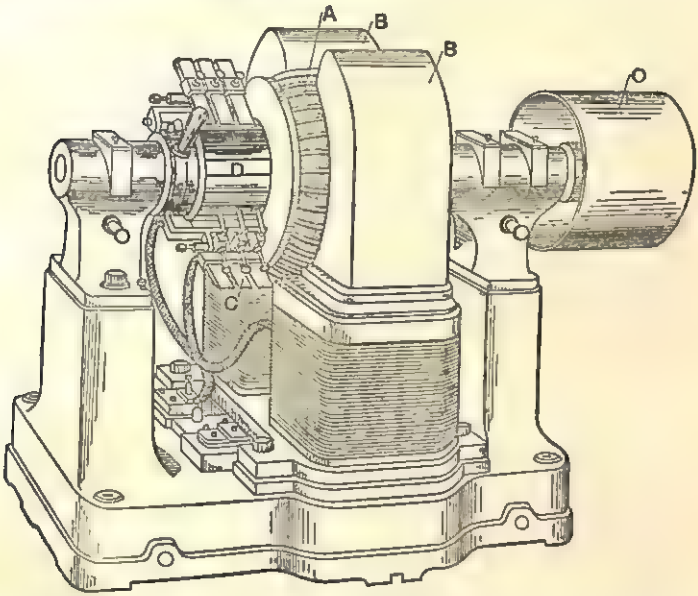


Fig. 45.—A Dynamo
A, Armature. B, B, Magnet. C, Pulley for a driving belt. D, Commutator.

Plunge the magnet into the coil; notice the galvanometer. When the galvanometer needle is steady again, remove the magnet quickly from the coil, and watch what happens.

58. Find the effect of moving a coil near a magnet.
Repeat experiment 57, moving the coil instead of the magnet.

You have from experiments 57 and 58 learnt two most important facts about magnets and electricity, viz.,

A current of electricity can be produced by *moving* (i) a magnet near a coil, or (ii) a coil near a magnet.

You will notice that in order to produce a current of electricity you have to move something; you are really changing motion energy into electrical energy.

This is what is done in the dynamo. This machine is very similar to the motor in construction, but it is worked in the opposite way. The armature is made to rotate between the poles of the magnet; this movement causes a current to flow in the wire of the armature when it is joined up in a circuit.

In the power stations of England, the energy necessary to turn the armatures of the dynamos is generally obtained from coal burning in the furnaces of steam engines. In countries where there is a great deal of falling water, this is used to turn turbines, and these turbines are made to rotate the armatures of dynamos. This method enables a country like Switzerland, which has practically no coal, to obtain a supply of electrical energy much more cheaply than would be possible if imported coal were the only source.

Notebook Summary.

M. 3. DYNAMOS

(circuit; electric current; fixed; magnet; moved; wire.)

If a coil of wire forming part of a –1– is moved near a magnet, an –2– will flow in the wire. The same is true if the –3– is moved near the –4–.

In a dynamo, the magnet is –5–, and the wire is –6–.

Notebook Exercise.—Draw figs. 46 and 47; describe briefly how a dynamo works.

A.C. and D.C.

You have probably seen all-main wireless sets advertised for A.C. or for D.C. These letters stand for Alternating Current or Direct Current. In many towns, the current supplied is A.C. That means that it is flowing first in one direction and then in the opposite direction through the circuit; in other words, it alternates. This alternating (or changing) takes place very rapidly, about 100 times a second.

In fig. 46 you see a diagram of a dynamo which produces this kind of current. Each time the coil rotates, it produces a current first in one direction and then in the opposite direction. The fact that the current is alternating in this way makes no difference if we are using it for lighting a lamp. It is also used for driving electric motors, though some motors are made for D.C. For some purposes, e.g. electro-plating and accumulator charging, a direct current must be used. If the current supplied

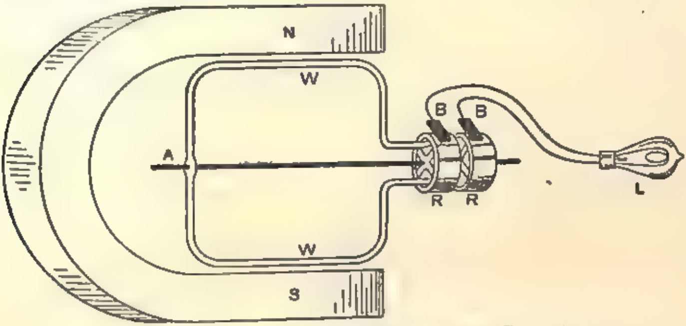


Fig. 46.—Dynamo producing Alternating Current

N and S, North and South poles of magnet. W, W, Coil of wire. A, Spindle on which coil revolves. R, R, Rings. B, B, Carbon brushes. L, Electric glow lamp.

is A.C., it is necessary first to change it to a direct current; this is done by a special machine, called a rectifier.

It is possible also to produce a direct current by using a commutator in the dynamo as shown in fig. 47.

You may be interested to know that electric waves start alternating currents flowing in wireless aerials. These currents alternate many thousands of times a second.

You may wonder why A.C. and not D.C. is so often supplied from power stations. The answer is that A.C. can easily, and without losing much energy, be "stepped up" to high voltages and "stepped down" to low voltages. This is very convenient for reasons which we

cannot discuss in this small book. You will, however, be interested to know a little about the machine called a transformer which is used for changing the voltage of a current.

To understand it, we must go back to Faraday's experiments. When he was trying to make a magnet produce

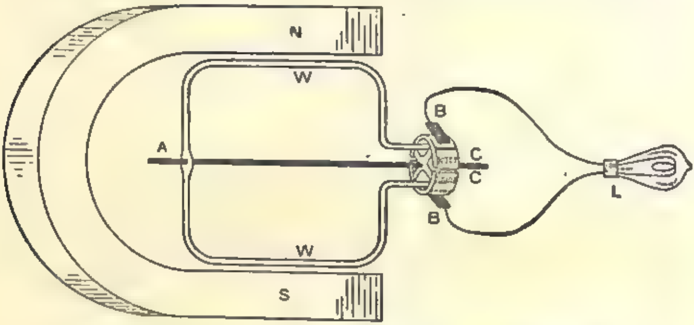


Fig. 47.—Dynamo producing Direct or Continuous Current

N and S, North and South poles of magnet. W, W, Coil of wire. A, Spindle on which coil revolves. C, C, Commutator (split ring). B, B, Carbon brushes. L, Electric glow lamp.

an electric current, he thought of trying with an electro-magnet. Like this:

59. Use an electro-magnet to produce an electric current. (See fig. 48.)

R—a ring of soft iron.

C1—a coil of insulated wire through which a current from a battery is passed when the switch S is closed.

C2—another coil connected by long wires X and Y to a galvanometer.

Watch the galvanometer as you switch the current on and off.

When you switch the current on and off, it produces the same effect as if you plunged a magnet into the coil C2 and then took it out again. The result is the same as you obtained in experiment 57 (p. 89); currents of electricity are produced in the coil C2. We call them induced currents.

If an alternating current from a dynamo is used instead of a direct current from a battery, there is no need to switch on and off. The alternating current produces the same effect as if you very rapidly plunged a magnet into the coil C2, took it out again, and plunged it in again, and so on. The result is that an alternating current is induced, as in experiment 59.

If the number of turns in coil C2 is 10 times the number of turns in coil C1, the induced current has a voltage 10

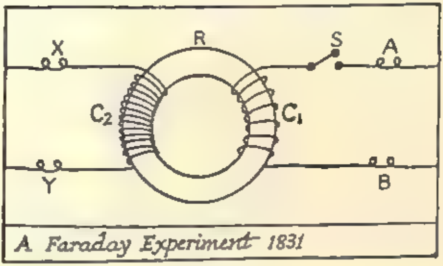


Fig. 48

times as high as the original current. That is how a transformer works; you see that it can be used for "stepping up" to high voltages or for "stepping down" to low voltages.

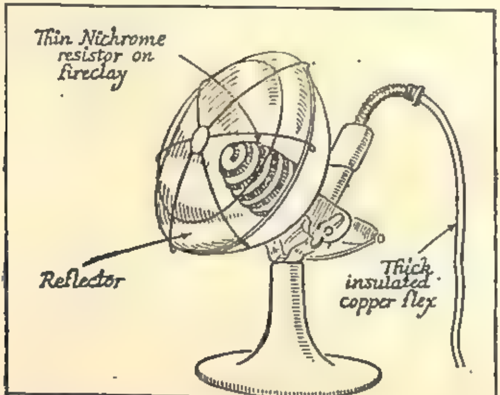
Electric Radiators and Lamps.

We have learnt that electrical energy can be changed into mechanical energy in an electric motor, into heat energy in an electric radiator, into light energy in an electric lamp.

Whenever a current flows in a circuit, some of the electrical energy is changed into heat. The flex leading to an electric radiator does not feel warm, but this is because very little heat is produced, and it passes away into the air as quickly as it is generated. Why does the radiator itself get hot?

If you examine the heating wires of a radiator you find

that they are not made of copper. As a matter of fact, they are made of an alloy of nickel and chromium called nichrome. This substance does not conduct electricity readily; we say it has a high resistance, and the nichrome wires are often called resistors. Copper, on the other hand, conducts electricity readily; it has a low resistance. It is this difference in resistance which causes the nichrome to get red-hot while the copper remains cold.



An Electric Radiator

Fig. 49

Resistance does not depend only on the substance of which a wire is made. It has been found that a thin copper wire, for example, has a higher resistance than a thick copper wire. That is one reason why flex is never made very thin; it is necessary to keep its resistance as low as possible. The nichrome wire, however, may be quite thin, for it is necessary to make its resistance high so that it will get hot.

Electric lamps are worked on the same principle as radiators. If you examine the resistor, you find that it is extremely thin; it is in fact generally called a filament (i.e. a thread). Its resistance is therefore very high;

this is important, for, in order to obtain light, it is necessary to make the filament not merely red-hot but white-hot.

The story of the gradual improvement in the construction of electric lamps is a very interesting one, for many difficulties have had to be overcome. Modern lamps are a great improvement on the earliest ones, but even now only about 5 per cent of the electrical energy they use is changed into light; the rest is wasted as heat.

Discussions.—(*a*) Difficulties overcome by inventors of electric lamps.

Consider: thinness and strength; melting-point (contrast with fuse wire); oxidation at high temperatures; fastening the filament in the glass holder (note the effect of expansion on heating).

(*b*) Why is the flex for an electric iron or radiator thicker than that used for an electric lamp?

(*c*) Flex must be thick so that its resistance is low; it must also be flexible so that it is convenient to use. How is it made both thick and flexible?

Why we have Fuse-boxes in Houses.

Occasionally when using electrical apparatus, e.g. an electric iron, something goes wrong; the current suddenly stops and the iron cools. This means that the circuit has been broken somewhere; the first place to look is in the fuse-box. There you see some terminals joined by short pieces of wire made of a white metal; these pieces of wire are called fuses. On examining them closely, you perhaps find that one of them is broken, and the broken ends look as if the wire has been melted. It is quite easy to repair this part of the circuit by joining the terminals again with a new piece of fuse

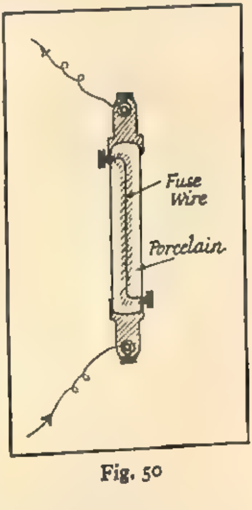


Fig. 50

wire of the same thickness as before. Before you do so, turn off the main switch. Why?

We must now ask what went wrong to cause the fuse wire to melt. If you examine the flex leading the current to and from the electric iron you may find the cause of the trouble there. In order to understand what may go wrong, you must know what the inside of a piece of flex is like.

60. Examine a short piece of flex such as is used for electric cleaners or fires.

Notice that although it is bound up to look like one wire, it really consists of two separate ones each made of many strands. Why are two necessary?

Try to explain why the various coverings are necessary.

Sometimes the bare ends of wire at the terminals of an iron or some electrical machine get worn and out of place. A strand of the wire bringing the current may then touch a strand of the wire which takes the current away. When this happens, the current flows through the new shorter circuit instead of through the iron or machine. We say the current has been "short-circuited". The new circuit is a much easier path for the current than the old circuit; it offers less "resistance" to the flow of electricity.

61. Find the effect of lowering the resistance in a circuit. Use the apparatus as in experiment 43 (fig. 37, p. 75). For H substitute about 4 yd. of very thin bare iron wire such as a florist uses. Touch K with the wire at different distances from the junction with F. Watch the light.

You notice that as you reduce the resistance by shortening H, the light becomes brighter. This is because the less the resistance, the stronger is the current which flows.

If, when using an electric iron, you accidentally make a short circuit, a much stronger current flows in the new low-resistance circuit than in the original high-resistance circuit. A short circuit may cause the current in wires in a household circuit to be 200 times as strong

as the current usually is. Such a strong current, if it were allowed to flow for any length of time, would cause a good deal of damage. It would make even the copper wires so hot that they might set fire to the woodwork near them. You must remember that this might happen anywhere in the circuit, because the strength of the current is the same at every point in it. That is why the electrical engineer puts a fuse wire somewhere in the circuit. This wire melts very easily when warmed. The result is that if, owing to some accident, a very strong current flows, the fuse wire melts, the circuit is broken, and the current stops; it is all done in about a second or less—before the copper wire has become hot. You see, then, that a fuse is a kind of safety-valve to shut off the electric current if for any reason it becomes too strong.

Discussions.—(*a*) Why is fuse wire not insulated in the usual way with cotton, or silk, or rubber? How is it insulated?

(*b*) Why should you avoid pulling electrical apparatus about by the flex?

(*c*) When putting electrical apparatus away, always wind the flex *loosely* round it. Why?

Notebook Exercise.—Explain why fuses are necessary.

How Electricity is Measured.

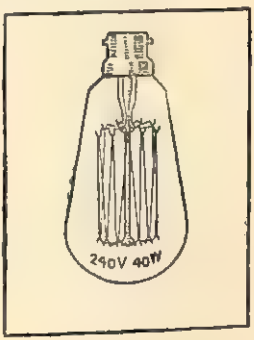


Fig. 51

If you look at an electricity bill you find that people are charged for the "units of energy" consumed. This is similar to the gas bill; there they are charged for the number of therms they have used. As we learned in Book II (p. 85) a therm is a unit of heat energy. What is the unit of electrical energy?

You will find a clue if you examine some electric lamps. On them are figures and letters, e.g. 240V 40W, or 240V 60W. The V, as you know, stands for volts

(see p. 83). All the lamps in a house will be marked for the same voltage, but other numbers vary. In a small bathroom you may have a lamp 240V 25W, in the kitchen 240V 40W, in a larger room 240V 60W. The more powerful the lamp, the larger the number before the W. You have perhaps guessed that W stands for some unit of power; it is called the watt. A 60-watt lamp uses twice as much energy every minute as a 30-watt lamp.

The units of energy charged for on the electricity bill are Board of Trade Units (B.O.T.U.). Here is an easy way of remembering what a B.O.T.U. is. Imagine a school hall lit by ten 100-watt lamps. Every hour the lamps are alight they use 1 B.O.T.U. It is 1000 watts for one hour, and is often called a kilowatt-hour.

Knowing this, it is easy to find how long a lamp can be alight before it will have used one B.O.T.U. All you have to do is to divide 1000 by the number of watts marked on the lamp; that gives the number of hours you want to know. Thus a 25-watt lamp can be alight for 40 hours before it will have used 1 unit of electricity.

The cost of electricity varies a great deal. In some towns it is as cheap as 1*d.* a unit; in others it may be 5*d.* At 5*d.* a unit you can have your bathroom lit with a 25-watt lamp for 8 hours at a cost of a penny.

Calculations.—(*a*) Choose some room lit by electricity. Find the cost of lighting it per hour.

You need to know (i) the total wattage of the lamps in it, (ii) the local price of electricity per B.O.T.U.

(*b*) Examine as many different pieces of electrical apparatus as you can. Notice the number of watts marked. Then find the cost per hour of using them. Tabulate the results for reference.

Notebook Summary.

M. 4. How Electricity is Measured

(Board; energy; hour; kilowatt-hour; ten; Trade; 1 B.O.T.U.)

Electricity is measured in –1– of –2– Units (B.O.T.U.). Another name for the unit is a –3–.

If –4– 100-watt lamps are alight for one –5–, they will use –6– of electrical –7–.

Electric Sparks and Lightning.

When putting a plug into an electric "point" you have probably noticed blue sparks. It is possible to make them also if you bring the terminal wires of a dry battery very close together. In Book II we learned one important use of an electric spark, viz. for igniting the mixture of petrol vapour and air in the cylinder of a petrol engine.

In experiment 43 (p. 75) we found that air was a bad conductor of electricity. This does not mean, however, that electricity can never under any conditions pass through air. If the air-gap in a circuit is small and the voltage is high, the electricity "jumps" across the gap; the current flows and a spark is formed. This is what happens in a sparking plug in the engine of a motor-car. You see in fig. 52 that the air-gap at A is very small; it is in fact about the thickness of a penknife blade.

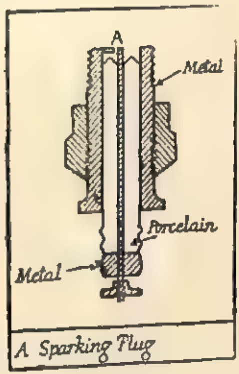


Fig. 52

When you make an electric spark in the air you are making lightning on a small scale. You have probably read how in 1752 Benjamin Franklin with his kite first proved that lightning and electric sparks were the same. Lightning is the spark caused by a current of electricity passing through the air from cloud to cloud or from a cloud to the earth.

When you make electric sparks, you hear crackling noises. These are caused by movements of the air, started by the heat produced by the spark. Thunder is simply the crackle of the spark we call lightning. As flashes of lightning may be thousands of feet long, it is not surprising that thunder is so loud.

You have perhaps heard a crackling noise as you combed your hair with a vulcanite comb. This is caused

by sparks from the comb, which has become charged with electricity. If after combing your hair you put your finger near the points of the comb, you can often produce some feeble electric sparks which can be seen in a dark room. Artificial silk clothes, by rubbing against other clothes, often become charged with electricity; they then crackle when you move them. It is dangerous to "dry-clean" silk with petrol, for it is possible to produce electric sparks sufficient to ignite the petrol vapour. (See Book II, p. 22.) Petrol itself is electrified by being shaken about, but the electricity is generally conducted away through metal to the earth so that there is no danger of sparking.

The Greeks, 2500 years ago, were aware of the fact that if either amber or jet were rubbed, it would then attract light things like feathers. But it was not until the end of the sixteenth century that Gilbert (one of Queen Elizabeth's physicians) discovered that glass, sulphur, and many other substances behaved in the same way. Gilbert wanted a word to describe all the substances which possessed this curious property when they had been rubbed. He thought of the Greek word for amber, *electron*, and he invented the word *electrics*. From this word we get the word electricity.

When you rub the top of your fountain-pen with a dry piece of flannel it is charged with electricity; we say it is electrified. It will attract little pieces of tissue paper, but there is not enough electricity at any one spot to get a spark from it. Electricity seems, however, to crowd on to points; that is why you can get sparks from a comb.

Discussions.—(*a*) Why are lightning conductors pointed? How do they work?

(*b*) When large quantities of petrol are sent through rubber hose-pipes, the pipes are earthed by means of wire. Why?

How a Sparking Coil is made.

In order to produce an electric spark two inches long, a voltage of 40,000 is required. You can imagine the

tremendous voltage of the current which rushes from one cloud to another and makes a flash of lightning several miles long. The current supplied by a pocket-lamp battery produces a very feeble spark, for its voltage is only about 4·5. It is possible, however, to change a battery current into a high-voltage current just as A.C. can be "stepped up" to high voltages by a transformer (see p. 93). Since the battery current is D.C., a different kind of apparatus is necessary; it is called a sparking

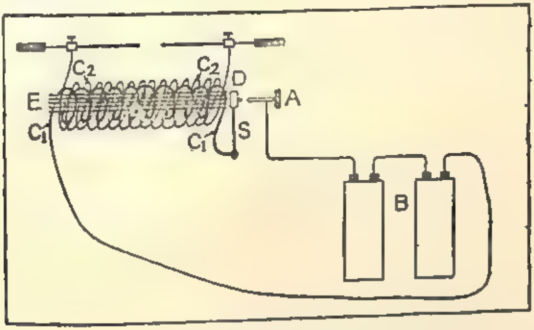


Fig. 53.—An Induction Coil

A, Adjustable screw. B, Battery. C_1, Primary Coil. C_2, Secondary coil. D, Piece of iron held against A by a spring S. E, Core of iron wires.

coil or an induction coil. You have probably played with a small one which you called a shocking coil. It consists really of two coils of insulated wire as shown in fig. 53. The coil through which the current is sent is called the primary coil; it consists of a small number of turns of fairly thick wire wound round a bundle of iron wires. The other, called the secondary coil, consists of a very large number of turns of fine wire.

You see that the current is made and broken as it is in an electric bell. Every time the circuit is "made", the iron core becomes a magnet; then the circuit is "broken", and the iron core ceases to be a magnet. This is like the

transformer; a current is induced in the secondary coil. As the secondary coil has many more turns in it than the primary coil, the voltage of the induced current will be much higher than that of the battery current.

A New Kind of Electric Light.

You have probably seen long brilliant tubes of coloured lights used for advertising. One of the most popular is a bright red light. If you examine the tube, you find there is no glowing filament inside. The red light is more like an electric spark. It is in fact produced by passing electricity through the gas called neon (see Book II, p. 9).

Fig. 54.—A "Vacuum" Tube

The tube (called a neon tube) contains a very little neon so that the gas is at a low pressure.

It has been found that if gases are at low pressure, their electrical resistance is much less than it is at ordinary pressures. It is therefore possible to send electricity through long tubes, and it is not necessary to use a very high-voltage current.

The tubes used are often called "vacuum" tubes. This is not strictly correct, for they really contain very small quantities of gas. The colour of the glow produced depends on the kind of gas used and also on the pressure of the gas.

Vacuum tubes containing air are often used (see fig. 54). The electricity is taken in to a conductor A; it passes through the rarefied air to another conductor C, and in so doing, it does not produce a spark but a glow. Under certain conditions, the electrodes (as A and C are called) begin to glow, a dark space appears near C, and then the

whole tube emits a green light. Men of science have discovered that this light is caused by a stream of tiny particles which travel away from C in straight lines. These particles are tinier than anything you have yet heard of, tinier even than atoms. They are actually particles of electricity and they are called electrons. They were discovered in 1897 by Sir J. J. Thomson.

You see that we have been quite right to talk about a current of electricity flowing. In a live wire there actually is a stream of these tiny particles of electricity (electrons) rushing along—billions of them every second. Wire always contains electrons, but until its ends are joined to the terminals of a battery or a dynamo, the electrons do not begin to flow. You can think of batteries and dynamos as being pumps which exert a special kind of force—electro-motive force. When a conductor is joined up to them, this special force makes electrons which are in the conductor move along it; this stream of electrons we call a current of electricity.

We have, however, been wrong in one way. In the wires of a circuit, the electrons are moving, not from the + to the — terminals, but in the opposite direction. When it was first decided which terminal should be called +, electrons had not been discovered. No one knew which way the electricity was flowing, but men of science all agreed to use the same method. By the time electrons had been discovered, everybody was used to the names of the terminals as they had been fixed, and they have never been changed, although we now know them to be wrong.

How X-rays are produced.

You have all heard of X-rays, and you know that they are used for taking photographs of parts of our bodies where ordinary light rays cannot penetrate. X-rays affect a photographic plate as light rays do, but unlike light rays they can pass through such substances as flesh, leather, and even black paper. Dense substances such as bone and metal are, however, more or less opaque,

even to X-rays. You can now understand how X-ray photographs are taken.

X-rays were discovered in 1895 by Röntgen, a German. He was experimenting with a vacuum tube wrapped in

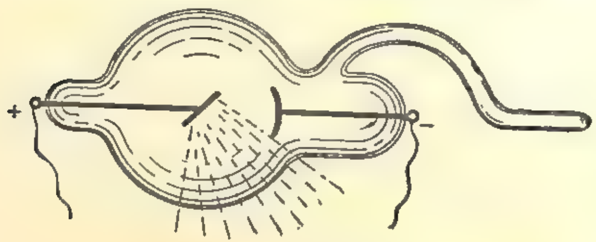


Fig. 55.—An X-ray Tube
The dotted lines are drawn to show where the X-rays are formed. The actual rays are, of course, invisible.

black paper, when he happened to notice that a screen nearby, covered with a sensitive salt, began to glow. He guessed that some invisible rays were coming through the black paper. They could not be rays of light; not

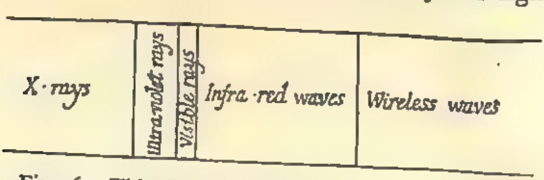


Fig. 56.—This diagram illustrates the fact that waves of various lengths travel through the ether. Which waves are contained in sunlight? See Book II, p. 111.

knowing what they were, he called them X-rays, i.e. the unknown rays.

We now know that X-rays are very short ether waves. They are set up when the electrons streaming from the negative electrode strike the surface of the glass or any other solid (see fig. 55).

SHOWING FRACTURE OF THE ULNA

E 620

SHOWING A BULLET IN THE HAND

X-RAY PHOTOGRAPHS

By courtesy of the Middlesex Hospital, London

Facing p. 104

The Wonders of Radium.

You have probably heard of a very valuable substance called radium. It was given this name because it is continually giving off rays, and, as you know, these rays are now used in hospitals to help to cure people of various ailments.

There are several substances which send out rays like radium. The rays were first discovered in 1896 by a Frenchman, Becquerel. He found that a photographic plate placed near a mineral, uranium, was affected even though it was wrapped in black paper so that no light could get to it. He decided that uranium must be giving off some invisible rays which, like X-rays, could penetrate black paper. Soon afterwards, Madame Curie, a Polish lady who married a French man of science, found that another element, thorium, behaved in the same way. These substances which sent out invisible rays were called radio-active substances.

In 1898, Madame Curie found a new element which was far more radio-active than either uranium or thorium; she called it radium. It is very rare; in order to get a few grains of it, Madame Curie had to use several tons of an ore called pitchblende.

Many experiments have since been made to find out what these mysterious rays are, and to explain how they are made. We now know that radium is continually sending out streams of electricity, and in doing so it also produces heat which warms the surrounding air. Part of this stream of electricity consists of electrons; part of it consists of much heavier particles whose electricity is of a different kind.

The two kinds of electricity are called positive and negative. Electrons are particles of negative electricity; it is the kind with which your fountain-pen is charged after you have rubbed it on your coat. Positive electricity is the kind with which glass is charged when you rub it with silk.

Mixed with the stream of two kinds of electricity sent out by radium there are ether waves—X-rays of very short length. These are probably started in some way by the movement of the particles of electricity.

It is a remarkable fact that radium can produce heat and send out electricity all by itself. In order to start a stream of electrons flowing in a wire joined to the terminals of a dynamo, we have to turn the armature; we have to use mechanical energy. In order to start a stream of electrons flowing in an X-ray tube, we have to use electrical energy. Radium, on the other hand, is continually giving out heat and electrical energy, and yet no energy of any kind is supplied to it. You think, perhaps, that radium is burning, like coal or phosphorus. This cannot, however, be the explanation, for radium does not use oxygen; no oxides are formed and it does not increase in weight (refer to Book II, pp. 7–12). On the contrary, it slowly but surely *loses* weight. It gives out heat and electricity and becomes lighter.

The secret is that *radium is made of electricity*. It seems hard to believe that a solid substance like radium can actually be made of electricity, but men of science tell us that it is so. The atoms of radium, made of particles of electricity, are always splitting up; the result is that radium is always shooting out electricity.

This is not the whole of the wonderful story of radium. An Englishman, Rutherford, discovered that after the radium atoms had lost some of the electricity of which they were made, they were still atoms, but not radium atoms. They gradually change until in the end they become atoms of lead. Once again we learn that it is impossible to get energy for nothing; radium gives out energy, but it is slowly being changed into lead.

You have probably heard of the alchemists and their search for the "philosopher's stone". These men thought it was possible to change common metals into gold, and they performed many experiments trying to do so. Their search was, of course, quite fruitless, but it is interesting

to know that their idea that one metal could be changed into another was not altogether wrong.

One modern discovery has followed another, and to-day we are told that all atoms—lead, gold, oxygen, hydrogen, &c.—are probably made of electricity. In Book II (p. 108) we learned that there were 92 different elements; now we learn that they are probably not so different after all.

Men of science are beginning to think that every element may be made of electricity. If this is true, it is possible that some day we shall be able, by "splitting" atoms of common substances, to obtain from them endless stores of energy. If at the same time we can invent ways of harnessing this energy, we shall then be no longer dependent on fuels such as coal and oil.

Storehouses of Energy.

Whenever we see anything moving, we know that energy is being used. If we want to move anything, we must obtain energy from somewhere. Primitive man depended very largely on the energy stored in food; in modern life we use a great deal of energy which has been stored in fuels of various kinds. It will now be interesting to collect together the various storehouses from which energy can be obtained when we need it.

(*a*) *Food.*—When you see any living creature moving itself or other things about, you know it is using energy which was once stored in food. The energy came from the sun; it was caught and stored by green plants; it was released again by oxidation in muscles.

(*b*) *Springs.*—As you look at the hands of a watch moving round, ask yourself where the energy is coming from.

It is coming, of course, from the spring which is slowly unwinding; the energy stored in the spring came from the muscles of someone's fingers. We may say, therefore, that the hands of a watch are really being moved by sunlight energy. This energy was first caught

and stored by green plants; it was released by oxidation in muscles; it was then stored again in the spring, and now it is being released once more, a little at a time.

It is possible to store energy in a steel spring, because if you change the shape of steel, it tends to move back to its original shape. We say it is elastic. All solids are elastic, but some are much more so than others. Steel, for example, is very elastic; lead is much less so. That is why springs are made of steel and not of lead.

A catapult is an example of a machine for storing muscular energy; it is different from a watch spring because the store of energy is released suddenly instead of gradually. In order to release energy stored in elastic solids, all you have to do is to let them go.

Notebook Exercise.—Add examples to the following lists:

Springs used for Storing Energy

(Think whether the energy is released slowly or quickly, and try to find a reason.)

Spring mattress.
Spring in door-lock.

(*c*) *Things high up.*—In grandfather clocks, the energy is not stored in springs. To wind up the clock, you lift weights on pulleys high up in the clock-case, and as they slowly fall during the week, they move the wheels which turn the hands round the clock face. The muscular energy of the clock-winder is stored in the weights as they are lifted up. As you look around, you can see hundreds of things which have been lifted up above the earth's surface; they are all storehouses of energy. In order to release the energy, all you have to do is to allow these things to fall. Most of the energy of falling things is usually wasted as heat; in order to use it, you need special machinery, as in grandfather clocks.

An important storehouse of energy is water which has evaporated, and has in this way been moved high up by

energy from the sun. The energy of falling water, as we have learnt (p. 90), is now sometimes used to drive turbines; these turn the armatures of dynamos and the motion energy is changed into electrical energy which can then be used for many purposes.

(*d*) *Things on the move.*—When we want to release energy from things which are high up, we start them falling. In other words, we set them on the move. Anything which is moving is a storehouse of energy.

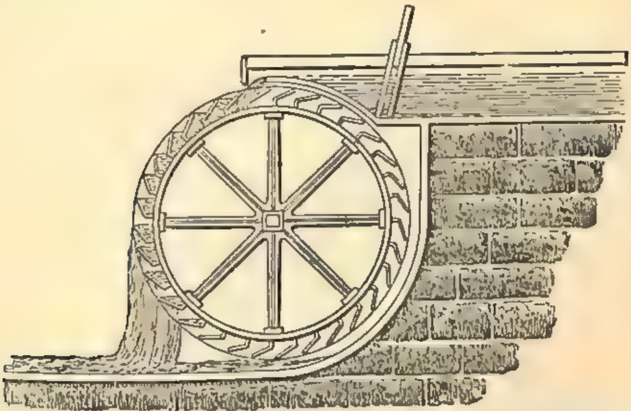


Fig. 57.—A Simple Method of Harnessing the Energy of Falling Water

An important example of this kind of energy storehouse is the wind. We catch and use its energy by means of sails, either on ships or windmills. Another example is the energy of tides; attempts are still being made to harness and use the energy of this ever-moving water, particularly in tidal rivers.

(*e*) *Fuels.*—As we watch steam engines, motor-cars, and aeroplanes moving about, we are reminded that all fuels are storehouses of sunlight energy. It is released in the form of heat by oxidation in engines and is then used to move machinery. Sometimes, like the energy of falling water, it is used to turn the armatures of dynamos

and is converted into electrical energy before it is used to work machinery.

You see that dynamos are generators and not storehouses of electrical energy. In a similar way, the engines we studied in Book II are generators and not storehouses of heat. This is one of the difficulties about energy in the form of electricity or heat; it cannot be stored in large quantities. It must be used as it is generated.

(*f*) *Electric Cells.*—We have learnt that energy is stored in foods and fuels, and that it can be released by oxidation. In other words, energy is released when foods or fuels join up (or combine) with oxygen to form oxides. This change, oxidation, is called a chemical change because it results in the making of different chemicals from those we started with.

Fermentation is another chemical change which results in the release of energy (see p. 59).

We must now find an answer to an important question: Are oxidation and fermentation the only kinds of chemical change which result in the release of energy? Try this experiment:

62. Add a little granulated zinc to some cold dilute sulphuric acid, and find what happens to the temperature of the acid.

(What gas will be made in this experiment? Refer to Book II, pp. 18–19.)

In experiment 62, you found that a good deal of heat was released. A chemical change took place, but the change was not oxidation. As a matter of fact chemical changes of many different kinds with many different substances are accompanied by the liberation of heat. Energy is stored in other substances as well as in foods and fuels. But if it is released in the form of heat as in experiment 62, it is extremely difficult to use it to do work. You can imagine, for example, how impossible it would be to produce heat from zinc and sulphuric acid quickly enough to run an engine: remember that most of the heat energy supplied to any

kind of engine is always wasted (refer to Book II, p. 84 and p. 98). It would be very expensive too. If we could release some of the energy in the form of electricity it would be more economical, for electricity does not escape into the air, as heat does.

63. To find if electrical energy is released when zinc is put in sulphuric acid.

Fit up apparatus as in fig. 58.

A—a beaker containing dilute sulphuric acid (1 volume of strong acid to 20 volumes of water).

C—a plate of copper.

Z—a plate of zinc.

S—a switch.

B—a current indicator, e.g. a sensitive electric bell, or a suspended compass needle.

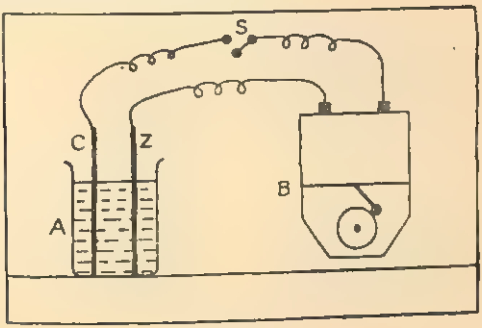


Fig. 58

Close the switch as soon as the metals have been put in the acid; repeat after a few minutes. Examine the plates (*a*) when the switch is open, (*b*) when the switch is closed.

In experiment 63 you find that it is possible to release energy in the form of electricity.

When the switch is open, you notice bubbles rising from the zinc; these are, as you know, bubbles of hydrogen. Nothing appears to be happening to the copper. As a matter of fact, copper is not affected by dilute sulphuric acid.

When the switch is closed, a current of electricity flows and bubbles are seen on the copper plate and rising from it. This does not mean that the copper is dissolving; if you weighed the copper after using the apparatus for a long time, it would still weigh the same as at the start. It is the zinc which is dissolving and liberating the hydrogen.

The beaker containing the acid and the metal plates is called an electric cell. You find that such a cell only makes electricity flow for a short time. If, however, you

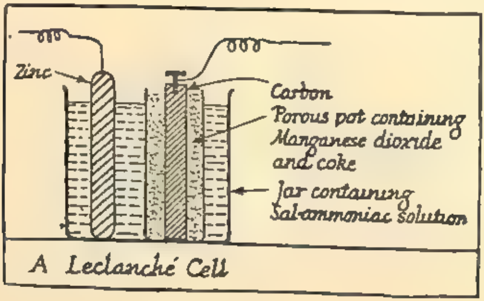


Fig. 59

wipe the hydrogen bubbles off the copper plate you find that the current flows again. It is this collection of hydrogen bubbles which stops the current, and one of the problems in making good cells is to get rid of any hydrogen which may be formed.

The simple cell used in experiment 63 is obviously not a good cell. Many different kinds have been tried, and to-day practically all cells which are commonly used are the kind called Leclanché cells.

64. Examine a Leclanché cell.

Notice that it consists of two parts. The outer jar contains a zinc rod in a solution of sal-ammoniac. The inner jar is a porous pot containing a carbon rod in a mixture of coke and manganese dioxide.

The chemical changes which take place in a Leclanché cell are difficult for you to understand; the important point is that, when they occur, electrical energy is liberated and an electric current is made to flow in the circuit.

The chief changes which take place are: (i) the zinc dissolves slowly; (ii) hydrogen and ammonia gas are formed, and electrical energy is set free; (iii) oxygen is required in the porous pot to get rid of the hydrogen. It does so by combining with the hydrogen to form water.

The necessary oxygen is obtained from the manganese dioxide, which then absorbs a new supply of oxygen from the air among the coke.

65. Examine a dry battery.

Use an old battery and take it to pieces. Notice that it consists of 2 or 3 cells: why is it made like this and not as one large cell? The cells are of the Leclanché type. A piece of muslin is often used instead of a porous pot; the sal-ammoniac is mixed with other substances to form a paste or jelly; the cell cases are made of zinc so that no separate zinc rod is required

Notice the holes in the pitch which seals the battery at the top; why are they necessary?

It is not difficult to guess how men first discovered fire; when they did so, they would notice at once the heat which was set free. You may be wondering how they discovered that some chemical changes release electrical energy, for small currents of electricity are not noticed so easily as heat; the current produced by a simple cell, for example, gives you no shock. You will not be surprised to learn that whereas fire was discovered in prehistoric times, the electric cell is quite a modern invention. The discovery which led to the invention of cells was made accidentally at the end of the eighteenth century by Galvani, an Italian Professor of Anatomy. He noticed when dissecting dead frogs that their legs sometimes twitched when touched by a knife. He knew that electricity produced by rubbing certain substances would give a shock and he naturally thought that the twitching

might be caused by electricity. At first he thought that frogs' legs must contain electricity; later it was, however, proved by Volta, another Italian, that the electricity did not come from the frogs; the current was started by the salt solution and metals used in the experiments. The frog's leg was only the indicator that energy was being released, just as the bell or the compass needle in experiment 63 was the indicator that energy was being released in your simple cell.

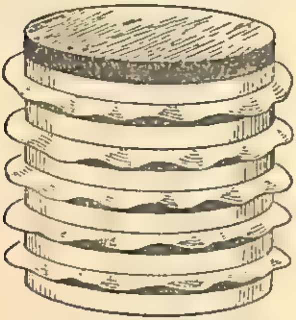


Fig. 60.—Volta's Pile

It was made of discs of copper and zinc separated (as shown in the drawing) by paper which had been soaked in dilute acid.

Volta made the first electric battery as shown in fig. 60. It was called Volta's Pile.

Another important kind of cell is the one you use for the low-tension current in wireless sets. It is generally called an accumulator or a storage cell.

66. Examine an accumulator.

Notice its weight. What are the plates made of?

The liquid is dilute sulphuric acid. How can you test that it is acid?

When an accumulator is "run down" you take it to a shop to have it "charged". The electrician sends a current of electricity (D.C.) through it for several hours, and then it is ready for use again. The following experiment illustrates what happens when an accumulator is charged.

67. Make and charge a simple accumulator.

Fit up apparatus as in fig. 61.

A—a beaker containing dilute sulphuric acid (1 volume of strong acid to 10 volumes of water): lead plates 1 and 2.

B—a battery of dry cells.

S1, S2—switches.

L—a small electric lamp.

Close S2; what happens?

Open S2 and close S1; allow the current to run for 2 or 3 minutes.

Open S1 and close S2.

Repeat the experiment, allowing the current to run for 5 minutes with S1 closed. Examine the lead plates.

When the accumulator was being charged in experiment 67, you probably noticed bubbles of gas rising from the lead plate numbered 2; this gas is hydrogen. The other plate turned dark brown; the brown coloration is due to the formation of an oxide of lead called lead peroxide.

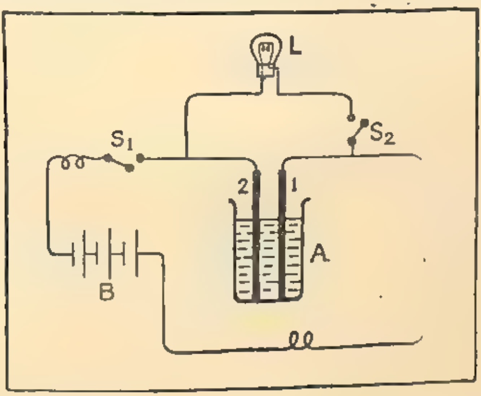


Fig. 61

The experiment is very like the one you did when you split up water by electricity (Book II, p. 17, experiment 19). Hydrogen is set free from one plate; oxygen at the other plate combines with the lead.

When the accumulator is charged, the two plates it contains are not exactly alike; one is a lead plate coated with spongy lead and the other is a lead plate coated with lead peroxide.

When the accumulator is used, the lead plate is oxidized and the brown oxide of lead is changed back to lead. When this chemical change takes place, electrical energy is set free just as it is in an ordinary cell.

You see that the usual names "accumulator" and "storage cell" do not mean that *electricity* is accumulated or stored in the cell; it is *energy* which is stored. This energy enters the cell as electrical energy; it is then changed into chemical energy and stored; finally it is changed again into electrical energy and released.

Notebook Summary.—Study the following table and try to reproduce it from memory:

M. 5. STOREHOUSES OF ENERGY

Storehouse	Energy Stored	How Released and Harnessed	Energy Released
(*a*) Food	Chemical energy (originally sunlight)	By chemical change (oxidation) in muscles	Muscular energy and heat
(*b*) Elastic substances (springs)	Muscular energy	By allowing the springs to move other things	Mechanical energy and heat.
(*c*) Things high up, e.g. (i) clock weights, (ii) clouds	Muscular energy Sunlight	By allowing things to fall and move other things	Mechanical energy and heat
(*d*) Things on the move, e.g. (i) hammer, (ii) wind	Muscular energy Sunlight	By arranging for the things to move other things	Mechanical energy and heat.
(*e*) Fuels	Chemical energy (originally sunlight)	By chemical change (oxidation) in engines	Heat
(*f*) Electric cells, e.g. (i) Leclanché (ii) accumulators	Chemical energy	By chemical changes in cells when a complete circuit is made	Electricity and heat

Moving on Land and Water, and in Air.

As you watch animals and things moving about, you can now remember: (i) they are using energy from one of the storehouses of energy studied in the last section; (ii) this energy is being used to move some kind of lever, e.g. legs, wings, wheels, propellers.

Birds beat the air with their wings and are able to lift themselves up and move rapidly about. Man has

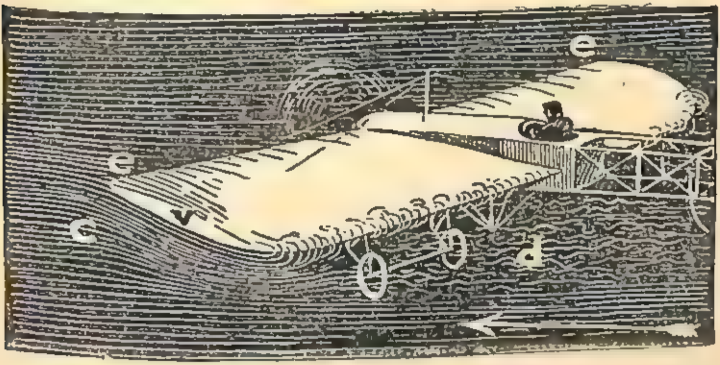


Fig. 62.—How an Aeroplane Flies

ee, "The entering edge". *c*, Air current deflected downwards, the reaction of which gives an upward thrust. *v*, Partial vacuum on top of plane. *d*, Air disturbed by plane. Arrow indicates direction of flight.

been unable to invent any machine which can move in this way. In order to fly he has to make use of the circular motion of propellers. These are really screws which, as they turn, work their way through air just as ordinary screws, when they are turned, work their way through wood. The aeroplane is thus pulled rapidly along the ground. Fig. 62 gives you some idea of how this heavy machine is then lifted into the air.

You notice that both birds and aeroplanes are heavier than air; if wings or propellers stop for any length of time, they begin to move down, pulled by the force of gravity. If birds or airmen keep control of their machinery,

they are able to make this downward movement gradually; they can volplane, i.e. glide safely to earth (see fig. 63). If, however, the machinery gets out of control, down they crash.

Birds and aeroplanes are not like balloons and airships; these can float in the air just as easily as ducks, corks and ships can float on water. Why do some things float while others sink? It has clearly something to do with their weight; we say, for example, that cork floats because

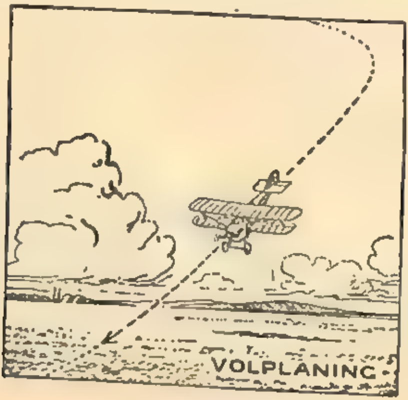


Fig. 63

it is less dense than water; iron sinks because it is denser than water. But many ships are made of iron; why do they float?

68. Why do iron ships float?

Take two tin lids of exactly the same size and weight. These will serve as models of iron ships. Float one of them in water. Hammer the other one into as small a lump as possible and put it on water.

In experiment 68, both iron ships weighed the same and yet one sinks and the other floats. The explanation is, of course, that the battered ship is practically a solid lump of metal, while the floating ship is only partly metal;

part of it is air. For its size, the floating ship is much lighter than the battered ship.

69. How much does a ship appear to weigh when it is floating? Suspend a toy ship from a spring balance. Notice its weight. Now lower the ship gently into water and watch the indicator of the balance.

You notice from experiment 69 that when a ship is floating its weight is supported by the water in which it rests. The water which is now round the ship (see fig. 65) is exerting just enough force to hold the ship up; that is

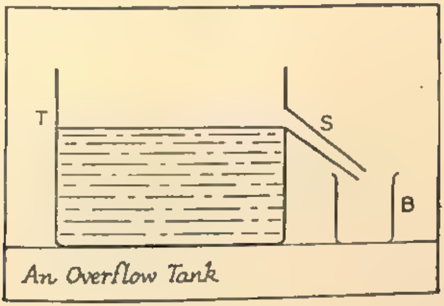


Fig. 64

to say, it balances the ship's weight. To do this, it must exert an upward force equal to the ship's weight. We say the weight of the ship is balanced by the upthrust of the water.

You have often noticed that ships floating in water push some water out of its place. We say they displace some water. The following experiment will help you to discover an interesting fact about the amount of water displaced by ships.

70. How much water does a ship displace?
Fill a tank T with water so that it is level with the spout S (see fig. 64). Gently lower a toy ship into the tank, collecting the overflow in a beaker B. Add ballast to the ship and notice what happens.

Now repeat the experiment with various toy ships. Compare each time the weight of the ship with the weight of the water it displaces. (A convenient way of doing this is to weigh the ship in grammes and measure the overflow in cubic centimetres in a measuring jar. Remember 1 c. c. of water weighs 1 gm.)

The heavier a ship is, the more water it displaces. From experiment 70, you find that the weight of water displaced by a ship is about the same as the weight of the ship. If you had better apparatus, you would find the weights to be still more nearly equal, for as a matter of fact, a ship does actually displace its own weight of

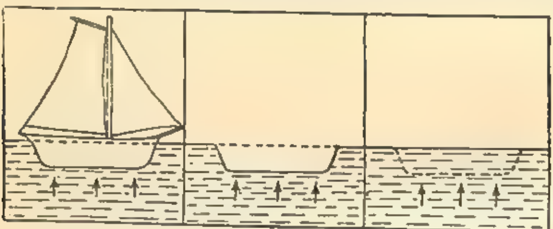


Fig. 65 (*a*) Fig. 65 (*b*) Fig. 65 (*c*)

water. This is only what you would expect, as you can understand if you think carefully about the problem. Suppose you could take the ship out of the water and keep the surrounding water still where it is as in fig. 65(*b*). What weight could this water hold up? The answer is that it could hold up the weight of water which would fill the space formerly filled by the ship (see fig. 65(*c*)).

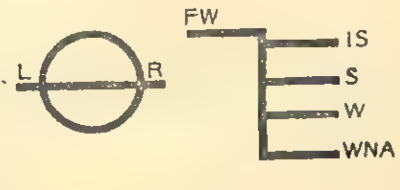
Discussions.—(*a*) Why were the results of experiment 70 not exactly correct?

(*b*) What is the Plimsoll Line? (See fig. 66.) The letters are abbreviations, thus:

LR—Lloyd's Register of Shipping.
FW—Fresh Water.
IS—Indian Summer.
S—Summer (temperate).
W—Winter.
WNA—Winter in North Atlantic.

Why are these different load lines allowed?

(*c*) If you hold a cork under water and then release it, why does it rise?



The Plimsoll Line

Fig. 66

(*d*) Why do balloons rise in the air? (Consider the weight of a balloon compared with the weight of air it displaces.)

Fig. 67.—Why do balloons rise in the air?

(*e*) Cork sinks in air but floats in water; iron sinks both in air and in water. Why?

Floating and Sinking.

Suppose you lowered a lump of solid iron into water as in fig. 68. You know it is too heavy to float; its weight will not appear to vanish as the weight of a ship does. What will happen?

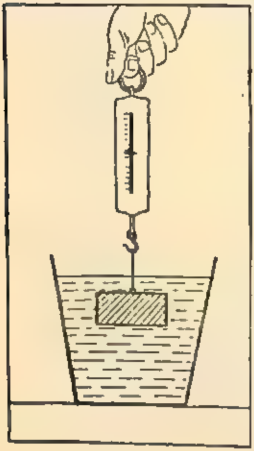


Fig. 68

71. How much does a 7 lb. iron weight appear to weigh when immersed in water? (See fig. 68.)

You find from experiment 71 that iron appears to weigh less when in water than it does when in air. (You have probably noticed a similar fact about your own weight when in the swimming bath.) It is due, of course, to the upthrust of the water.

This upthrust is not enough to support the whole weight of the iron. If, for example, a cubic foot of iron were immersed as in fig. 68, the upthrust on it would be enough to support a cubic foot of water. Since a cubic foot of iron is heavier than a cubic foot of water, the iron if let go would sink.

Discussion.—What will be the weight of the water displaced by the iron in experiment 71.

(Test your answer by doing an experiment. Instead of the bucket, use the apparatus shown in fig. 64.)

You have probably found both by thinking and by doing an experiment that the weight of water displaced by a lump of iron is equal to the amount which the iron appears to lose in weight when it is put in water. You see that this is really the same as you found about things which float; floating things appear, however, to lose all their weight when in water.

This fact about sinking and floating was first discovered by Archimedes about 2000 years ago. It may be stated shortly as follows: *weight in air — "weight" in water = weight of water displaced.* This must be true because both the "loss in weight" and the weight of the displaced water are really the same; they are both the same as the upthrust on the thing which is in the water.

The Meaning of Density.

When we say that iron is heavier than water we do not mean that any lump of iron is heavier than any quantity of water. We mean that a certain volume of iron is heavier than the *same* volume of water, for example, a cubic foot of iron is heavier than a cubic foot of water, and so on. Men of science try to be exact in their statements, and instead of saying that iron is heavier than water, they say that the density of iron is greater than the density of water. In a similar way, they say that things which float have a density less than the density of water.

You have often seen a live fish quite still in water; it neither sinks nor floats. This is because its density is practically the same as the density of water. It can, as a matter of fact, change its density slightly by filling or emptying a narrow bladder inside its body; this bladder is called a swim bladder. But most of the movements up and down in water are made by force exerted by the fish with its tail against the water; if, however, it does not use its muscles, it can remain motionless in still water.

Discussion.—Why is it not strictly accurate to say that the air at the top of Everest is lighter than the air at sea-level? (Refer to p. 13.)

Notebook Summary.

M. 6. Floating and Sinking

(air; Archimedes; displace; displaced; equal; floats; immersed; iron; less; less than; lose; part; ship; sinks; solid; upthrust; weight; 2000.)

When a ship floats, its whole –1– is supported by the –2– of the water. The weight of water –3– is equal to the weight of the –4–.

Iron –5– but an iron ship –6–. This is because the iron ship is not –7– iron. When it settles down in the water, it has displaced water –8– in weight to its own weight.

When solid iron is –9– in water, the weight of water displaced is –10– the weight of the iron. The upthrust of the water is therefore less than the weight of the –11–; that is why the iron sinks. The upthrust does, however, support –12– of the weight; that is why iron appears to weigh –13– in water than it does in –14–.

When things float or are immersed in water, the weight they appear to –15– is the same as the weight of water they –16–. This was discovered by –17– about –18– years ago.

Books to Read.—*How we Harness Electricity*, C. R. Gibson (Blackie); *Electricity as a Messenger*, C. R. Gibson (Blackie); *Telephones and Gramophones*, C. R. Gibson (Blackie); *Wireless*, C. R. Gibson (Blackie); *The Age of Machinery*, A. R. Horne (Blackie); *Electricity as a Wizard*, C. R. Gibson (Blackie); *Wonders of Transport*, C. Hall (Blackie); *The Mastery of the Air*, W. J. Claxton (Blackie); *The Airman and his Craft*, W. J. Claxton (Blackie).

Five-minute Lectures.—The books mentioned above contain numerous chapters dealing with suitable topics for interesting talks and discussions. There are, for example, many important uses of electricity which we have not been able to discuss in this book.

Notebook Summary.—Study the following table and try to reproduce it from memory:

M. 7. CHANGES IN THE FORM OF ENERGY

Energy	Changed by means of	Energy
1. Sunlight ..	Green plants	Chemical energy in food and fuel
	Evaporation of water	Energy of falling water
	Expansion of air	Energy of wind
2. Chemical ..	Oxidation in muscles	Muscular energy and heat
	Oxidation in engines	Heat
	Various other chemical changes	Heat
	Chemical changes in electric cells	Electricity and heat
3. Muscular ..	Friction	Heat and sound
	Machines and elastic substances	Mechanical energy, heat, and sound
4. Heat	Engines	Mechanical energy and sound
	Lamps	Light
5. Mechanical ..	Friction	Heat and sound
	Dynamos	Electricity, heat, and sound
6. Electricity ..	Electric bells	Mechanical energy, heat, and sound
	Electric lamps and heaters	Heat and light
	Electric motors	Mechanical energy, heat, and sound

CHAPTER V

Sensing

How we get News from the Outside World.

In Books I and II you have learnt something of what men of science can teach us about the way we get news through our ears and eyes and skin. We hear because air waves strike our eardrums; we see because ether waves strike our retinas; we feel heat because ether waves strike our skin.

In all these three examples, you notice that the news we get comes from a distance; we pick it up as a wireless receiver picks up wireless waves from a distant station. That is one reason why these senses are so important to us. We see and hear the approaching car and we avoid being run over; we feel the heat of a very hot gas-stove and we avoid getting burnt.

Some news, however, we do not get from distant stations in these ways. We may see an egg on our breakfast table, but until we get near to it, we do not know if it is good or bad. Important news of this kind we get at short range by smelling and tasting. In the dark, we often have to be content with short-range news. For example, we grope about with our hands stretched out; we have to touch things before we get any news about them.

How we get News by Smelling, Tasting, and Touching.

The nose, as we learned in Book I (p. 13), is an efficient filter for the air we breathe; it is also the organ of smell just as the eye is the organ of sight.

72. Hold something which smells fairly strongly, e.g. a rose or a piece of camphor, under your nose. What do you notice (*a*) when you hold your breath. (*b*) when you breathe out, (*c*) when you breathe in?

What do you do when you try to smell something which has only a faint smell?

Unlike sights and sounds, smells are not caused by waves. A thing which has an odour, for example a rose or a piece of camphor, is continually giving off very tiny particles of something. Some of them enter the nose with the air which is rushing in to fill the lungs. That is why you sniff when you try to detect a smell. In the upper part of the nose, the particles in the air affect some special cells which are connected to the brain by nerves. When this happens you notice the smell. You never mistake the scent of a rose for the smell of camphor, although both depend on such tiny particles floating about in the air. Try to think of all the different kinds of odours you know. You find they are as innumerable as the colours you see or the sounds you hear. The special cells in the nose are so sensitive that they are able to send hundreds of different messages to the brain; the exact message depends on the composition of the tiny particles which touch them. Smelling is a very mysterious and wonderful method of getting important news. It helps us to select our food; it helps us to enjoy it; it often gives us an appetite and makes our digestive juices flow more freely.

The mouth, as we learned in Book II (p. 25), is the first part of the tube in which our food is digested. The tongue is useful in helping us to masticate and swallow our food. It is also necessary, as you well know, to help us to make correct speech sounds. In addition to these two uses, it enables us to taste. The organs of taste are collections of cells, called taste buds; like all sense organs they are connected to the brain by nerves.

73. Place a little moist sugar on your tongue as far back as you can. What do you taste?

Now place some sugar near the tip of your tongue. (Refer to experiment 38, p. 69.)

Repeat the experiment using salt. Find where you must put salt to taste it easily.

Repeat the experiment using vinegar.

You learn from experiment 73 that you are sensitive to sugar at the tip of your tongue, to salt and vinegar at the sides. The taste buds in different parts of your tongue are not all sensitive in the same way. You taste sweet things with the tip, salt and sour things with the sides, and bitter things with the back of your tongue.

When you put sugar on the tip of your tongue you probably noticed that there was at first no taste. This is because we cannot taste anything until it has dissolved.

When you used vinegar, you noticed that it was possible to recognize it by smell before you tasted it. What we call taste is often the result of smelling as well as tasting. That is why nasty medicine does not taste so bad if you nip your nose while taking it. As a matter of fact, you can, with your tongue, distinguish only four different tastes—sour, sweet, salt, bitter; all other tastes are partly the result of smelling caused by particles floating into your nose either through your nostrils or from the back of your mouth.

Many animals appear to have a keener sense of smell than we have. When searching for food, the news they get by smelling is very important; it helps them to move in the right direction for tracking their prey and avoiding their enemies.

Discussions.—(*a*) When you have a cold in the head, your sense of smell is not as keen as usual. Why?

(*b*) Have worms, fish, birds, or insects any sense of smell? (Refer to discussion (*e*), p. 58.)

You will notice that before we get messages of smell or taste, things must actually touch us in special places. As a matter of fact, we receive messages of various kinds whenever anything touches our skin anywhere. We may feel whether things press against us hard or gently; we

may feel whether they are rough or smooth, hot or cold; if the things are sharp and they cut or prick us, we feel pain.

We have so far learnt that we get news of the outside world in the following ways:

(i) Air waves striking our eardrums (sound).

(ii) Ether waves striking our retinas (light).

(iii) Ether waves striking our skin (heat).

(iv) Tiny particles touching special cells inside the nose (smell).

(v) Solutions touching special cells on the tongue (taste).

(vi) Anything touching our skin (pressure, roughness, temperature, pain).

Pain is an unpleasant but important kind of news. It is Nature's danger signal that something is wrong. As we noticed in Book I (p. 112), a very loud sound may produce pain. Light and heat, if they are very intense, also cause pain. Again, pain is felt when anything goes wrong with the working of the body. We receive news, not only from the outside world, but also from the inside, from our own living machinery.

All these various messages are carried to our brains by nerves, and every kind of message has its own special set of nerves. We shall in the next section learn something about the mysterious nerves which make our bodies such wonderful receiving sets.

Notebook Summaries.

S. 1. Ways of Sensing

Write out from memory the list of the various ways of sensing given on this page.

S. 2. Smelling, Tasting, and Touching

(bitter; cells; dissolve; noses; pain; particles; roughness; salt; smelling; sour; sweet; temperature; tongues; touch.)

We smell things when –1– from them touch special –2– in our –3–.

We taste things when they –4– and some of the solution touches special cells in our –5–. There are only four different tastes: –6–, –7–, –8–, –9–. All other so-called tastes are partly the result of –10–.

We also get news of the following kinds when things –11– our skin: pressure, –12–, –13–, –14–.

Our Wonderful Headquarters.

As we have learnt, from every part of our bodies there are nerves. To look at, a nerve is very like a piece of white cotton. It is really made up of a number of fibres, each

Fig. 69.—Nerve Cells showing Fibres

one usually protected by a sheath of fat. A nerve is therefore very similar to an electric cable, both in construction and in usefulness. Unlike a cable, its messages are not ordinary electric currents. A nerve, we must remember, is alive; it consists of living cells each with its nucleus. (See fig. 69.)

The nerves from all parts of the body go into the spinal column. Here they connect up with a giant bundle of nerves called the spinal cord. The spinal cord connects up with the brain, a soft, whitish, wrinkly thing. The brain is built up of millions of nerve cells whose fibres are all intertwined in a very complicated way. And yet, as long as the brain is not injured, the messages of various kinds

from all parts of the body do not get mixed up. You can understand how important it is to protect both the brain and the spinal cord from injury; this is why they are enclosed in strong bony boxes.

So far, we have considered how messages are taken to the spinal cord and brain. What happens when they get there?

When you touch a hot gas-stove, you not only get the message that it is hot; you also move your hand away with a jerk. Your brain, on receiving the message, immediately sends other messages along other nerve fibres to muscles in your arm. As soon as the muscles receive their messages, they contract, and your arm quickly moves your hand away from danger.

You must remember then that there are not only nerves going from all parts of the body to the brain; there are also nerves coming back from the brain to all parts of the body. You can now understand a little more clearly how by sensing we are guided in making movements. Our sense organs gather news; a set of nerves carries this news via the spinal cord to our brains; another set of nerves takes a reply to the proper muscles; we then move in the proper way.

We may think of our brain and spinal cord as a wonderful kind of headquarters equipped with a marvellous arrangement of telephone wires. The incoming wires are always kept clear for receiving messages; special wires are provided for outgoing messages. Headquarters receives a message, Danger; it sends out a message to our muscles, and we move back. Messages come in, Hungry; answers go out, and we move off home and eat our dinner. Day and night an urgent message is continually coming in, Oxygen; messages are sent out incessantly, and we move so as to expand our chest cavities. The more you think about it, the more wonderful it is.

Notebook Summary.

S. 3. Nerves and Brain

(brain; muscles; nerve cells; nerves; sense organs; spinal cord.)

All parts of the body are connected with the –1– and the –2– by nerves. Some nerves carry messages from –3– to the brain; other –4– carry messages from the brain to –5–.

The brain, spinal cord, and nerves are built up of –6–.

Books to Read.—How you Work, I. Wilson (Howe); *The Wonders of the Human Body,* Shuttleworth (University of London Press).

CHAPTER VI

How Much have you Learnt?

In working through this book, it has often been necessary to refer to Books I and II. You will find it interesting to try how many of the questions in the last chapters of those books you can now answer.

When you have done that, here are a hundred questions about the lessons you have studied in this book. Check your results by the answers given on p. 140.

A Hundred Questions

As we breathe, we –1– and –2– our chest cavities by means of –3–. When our chest cavities are expanded, air is –4– into our lungs. This happens because the air we live in is –5– by the weight of air above. Compressed air –6– in all directions; this is why air always rushes into –7– spaces.

The pressure of the atmosphere at sea-level is about –8– per square inch. The –9– you go, the less this pressure becomes.

The pressure of water is like that of air; the –10– you go, the greater the pressure. If water is free to move, it does so until the whole of its surface is –11–.

A –12– is an instrument used for measuring –13– pressure. There are two kinds, –14– and –15–. Atmospheric pressure is enough to hold up a column of mercury about –16– high. In the British Isles, the barometer reading varies from just below –17– to just above –18–.

In a well-ventilated room, the air is kept (i) gently –19–; (ii) at a steady temperature, about –20–; (iii) neither over- nor under-charged with –21–.

When we are in good health, our body-temperature is about –22–. In hot weather we usually perspire more than in cold weather. As perspiration –23– from the skin, it uses –24– from

the –25–. Perspiration thus helps to keep our body-temperature –26–.

The body-temperature of fish is –27– than 98·4° F. As water cools, it –28– until the temperature reaches about –29–; then it begins to –30–. Water at freezing-point is therefore –31– dense than water which is not quite so cold. This explains why water in a pond –32– on top first.

Living things are composed of –33–. The living substance in cells is called –34–. A fully grown cell –35– into –36–; in this way new cells are formed. Most –37– things start growing from one –38– cell, which is formed by two special cells uniting. One of these cells, called an –39–, is formed in the seed-boxes of flowers and in the –40– of animals. When the ovum has united with the other kind of cell, the seed or egg is said to be –41–.

Yeast is a –42– which is not green; it belongs to the –43– class. It can obtain energy from sugar by –44–; the sugar is changed into –45– and –46–. Other members of the fungus class are –47– and –48–. They reproduce by means of –49–. –50– are the smallest of all greenless plants. Some, like those which cause humus to –51– and those which help animals to digest –52–, are useful; some, like those which cause disease, are dangerous. Dirt is dangerous because it contains –53–.

A –54– of soap in water is used for removing greasy dirt because it breaks up –55– into tiny particles; we say it forms an –56–.

Electricity is a form of –57–. It can be made to flow in –58– by means of –59– or electric –60–. Very bad conductors of electricity are called –61–.

Iron or steel can be magnetized by an –62– or by stroking with a –63–. A suspended magnet points N—S; the end which points to the north is called the –64–. The N pole of a magnet –65– the N pole of another magnet and –66– the S pole.

An electric motor consists of a –67– of wire which moves between the –68– of a –69–. When a current of electricity is sent through the coil, the coil becomes a –70– and is moved by the –71– of attraction and repulsion between itself and the fixed –72–.

A –73– is a similar machine worked the reverse way. The –74– is rotated between the poles of a magnet and this causes a current of electricity to flow in it.

Electricity will pass through air if the air gap is –75– or the voltage is –76–. If gases are at –77– pressure, their resistance is less than it is at –78– pressure.

Radium is a radio-active –79–; its –80– are breaking up and slowly changing into atoms of –81–. All atoms are storehouses of –82–.

Other storehouses of energy are: –83–; –84–; –85–; things –86–; things –87–; electric –88–.

The two commonest kinds of electric cells are the –89– cell and the accumulator. The plates in an accumulator are made of –90–; the liquid is –91–.

Odours are caused by tiny –92– given off by some substances. When these particles touch special –93– in the nose, messages travel along –94– to the brain and we then notice the smell.

The organs of taste are collections of cells on the –95–; they are called –96–. We taste –97– things with the tip, –98– and –99– things with the side, and –100– things with the back of the tongue.

Observing the World around Us.

We have now come to the end of our course in Science, and you should once again take a walk down a familiar street, noticing the scientific facts about the things around you. You will this year be able to describe your surroundings still more completely than you could last year.

As you look around, think first about the wonders of living things. The same ideas may strike you whether you look at a horse-chestnut tree in full leaf or at a strong carthorse toiling uphill; you cannot help thinking about the miracles of growth and movement. In order to grow and move, these living things must feed and breathe; in order to obtain food and air, they must move; in order to make proper movements, they must be guided by messages they get by sensing.

Choose the first living thing you see, and then think how much you know about the way it lives. How does it breathe, feed, and move? How are its movements guided? Can it see, hear, taste, smell, or feel?

Now go back in imagination to the beginning of its life, to the tiny cell from which it grew. Think how this cell began by the uniting of two parent cells, the pollen

cell and the ovum in the flower of the horse-chestnut tree, for example. Think then of the wonderful way in which, at a later stage, it began to germinate; how it absorbed food; how gradually it increased in size, as atoms of very common elements combined together to form molecules of new living protoplasm. At last the germ cell divided into two; the wonderful process of growth had then begun. Try to follow in imagination the wonderful transformation as this growth continued.

If you are looking at a tree, you will think about its roots pushing their way underground and absorbing dissolved salts from the soil; about the green leaves in sunlight feeding on carbon dioxide from the air and liberating oxygen. If you turn to look at a cart-horse, you will think about its strong muscles contracting and relaxing; about the energy released from food by oxidation, and the carbon dioxide which is formed.

These thoughts remind us of the wonderful way in which Nature works. Cycles of change are continually taking place, and in a marvellous way a proper balance is maintained.

Carbon dioxide is made by living things as one of the products of breathing, but the air never becomes overcharged with it; this is because green plants feed on carbon dioxide and liberate oxygen. The air, however, never becomes overcharged with oxygen; this is because living things use it for the oxidation of food. This is one example of how Nature keeps things balanced.

Nitrogen is one of the elements needed by plants and animals for building up new cells. It is taken out of the soil by plants in the form of nitrates and built up with other elements into new protoplasm. This contains the proteins needed by animals for the making of new animal protoplasm. Some of this material containing nitrogen is returned to the soil as manure or refuse; there it is converted into nitrates again by the action of bacteria. This is another example of a cycle of change, but we remember that, under modern conditions, the balance

of Nature has been disturbed. Only part of the nitrogen has been returned to the soil whence it came; it is necessary for man to help to restore the balance by using artificial fertilizers.

Man cannot interfere with the working of Nature for his own benefit without disturbing the balance of some cycle of change. For example, the invention of machinery has led to the growth of large factory towns where plants necessary for human food cannot grow; the problem of supplying these towns with food, however, is easily solved by transporting food from other parts. Some of the problems of big towns are more difficult to solve. How, for example, can the air of these towns be kept pure? How is household refuse to be got rid of?

Wherever we look, we see the results of Science. It has taught man to grow two ears of corn where only one used to grow; to move himself ten miles in the time formerly taken to travel one; to manufacture ten articles where formerly only one was made. But these benefits have brought with them many new problems which men of science to-day are trying to solve. The work of Science is never done.

The same is true of the study of Science. You have finished your course and may perhaps be leaving school. You have, however, only learnt a few of the main facts about the subject. Newton, a great man of science, said towards the end of his life that he felt like a man who had taken a walk on the seashore, finding a pebble here and a shell there; while the great ocean of Truth lay before him unexplored. We, in this course, have only been able to examine a few of the largest stones on the shore of scientific knowledge, but if you use your Public Library, you will be able to continue the course for yourself and each year learn a little more about this most important subject—The Science of Living.

INDEX

ANSWERS TO THE HUNDRED QUESTIONS

1. expand.
2. contract.
3. muscles.
4. forced.
5. compressed.
6. presses.
7. empty.
8. 15 lb. wt.
9. higher.
10. deeper.
11. level.
12. barometer.
13. atmospheric.
14. aneroid.
15. mercury.
16. 30 in.
17. 28 in.
18. 31 in.
19. circulating.
20. 60° F.
21. water vapour (moisture).
22. 98·4° F.
23. evaporates.
24. heat.
25. body.
26. constant.
27. lower.
28. contracts.
29. 39° F. (4° C.).
30. expand.
31. less.
32. freezes.
33. cells.
34. protoplasm.
35. splits.
36. two.
37. living.
38. germ.
39. ovum.
40. eggs.
41. fertilized.
42. plant.
43. fungus.
44. fermentation.
45. alcohol.
46. carbon dioxide.
47. mushrooms.
48. moulds.
49. spores.
50. Bacteria.
51. decay.
52. cellulose.
53. harmful bacteria.
54. solution.
55. grease.
56. emulsion.
57. energy.
58. conductors.
59. dynamos.
60. cells.
61. insulators.
62. electric current.
63. magnet.
64. N pole.
65. repels.
66. attracts.
67. coil.
68. poles.
69. magnet.
70. magnet.
71. forces.
72. magnet.
73. dynamo.
74. coil.
75. small.
76. high.
77. low.
78. high.
79. element.
80. atoms.
81. lead.
82. energy.
83. food.
84. springs.
85. fuels.
86. high up.
87. on the move.
88. cells.
89. Leclanché.
90. lead.
91. dilute sulphuric acid.
92. particles.
93. cells.
94. nerves.
95. tongue.
96. taste buds.
97. sweet.
98. salt.
99. sour.
100. bitter.